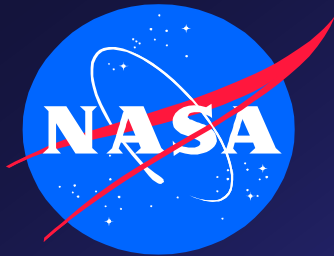


## Compression stockings may ameliorate orthostatic intolerance in astronauts after short-duration space flight

Steven H. Platts<sup>1</sup>, Stuart M.C. Lee<sup>2</sup>, Christian M. Westby<sup>3</sup>, L. Christine Ribeiro<sup>2</sup>, Michael B. Stenger<sup>2</sup>

*NASA Johnson Space Center*<sup>1</sup>, *Wyle Integrated Science and Engineering Group*<sup>2</sup>, and *Universities Space Research Association*<sup>3</sup>, Houston, TX

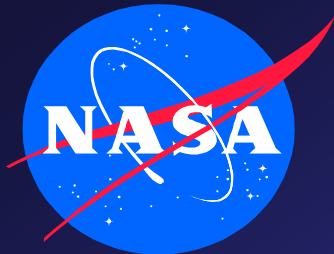
Orthostatic intolerance following spaceflight has been observed since the early days of manned spaceflight, and no countermeasure has been 100% effective. During re-entry NASA astronauts currently wear an inflatable anti-gravity suit (AGS) which compresses the legs and abdomen, but this device is uncomfortable and loses effectiveness upon egress from the Space Shuttle. We previously reported that foot-to-thigh, gradient compression stockings were comfortable and effective during standing after Shuttle missions. More recently we showed in a ground-based model of spaceflight that the addition of splanchnic compression to the foot-to-thigh compression stockings, creating foot-to-breast high compression, improved orthostatic tolerance in hypovolemic subjects to a level similar to the AGS. **Purpose:** To evaluate a new three-piece, foot-to-breast high gradient compression garment as a countermeasure to post-spaceflight orthostatic intolerance. **Methods:** Fourteen astronauts completed this experiment (7 control, 7 treatment) following Space Shuttle missions lasting 12-16 days. Treatment subjects were custom-fitted for a three-piece, foot-to-breast high compression garment consisting of shorts and foot-to-thigh stockings. The garments were constructed to provide 55 mmHg compression at the ankle and decreased gradually to 15 mmHg over the abdomen. Orthostatic testing occurred ~30 days before flight (without garments) and ~2 hours after flight (with garments for treatment group only) on landing day. Blood pressure (BP) and heart rate (HR) were acquired for 2 minutes while the subject lay prone and then for 3.5 minutes after the subject stood. Data are reported as mean  $\pm$  SE. **Results:** The compression garment successfully prevented the tachycardia and hypotension typically seen post-spaceflight. On landing day, treatment subjects had a smaller change in HR ( $11 \pm 1$  vs.  $21 \pm 4$  beats $\cdot$ min<sup>-1</sup>,  $p \leq 0.05$ ) and no decrease in systolic BP ( $2 \pm 4$  vs.  $-9 \pm 2$  mmHg,  $p \leq 0.05$ ). Garments also received good comfort ratings and were relatively easy to don. **Conclusion:** In this small group of astronauts, foot-to-breast high gradient compression garments seem to have prevented these negative effects of spaceflight on the cardiovascular responses to standing.



# Compression stockings may ameliorate orthostatic intolerance in astronauts after short-duration space flight

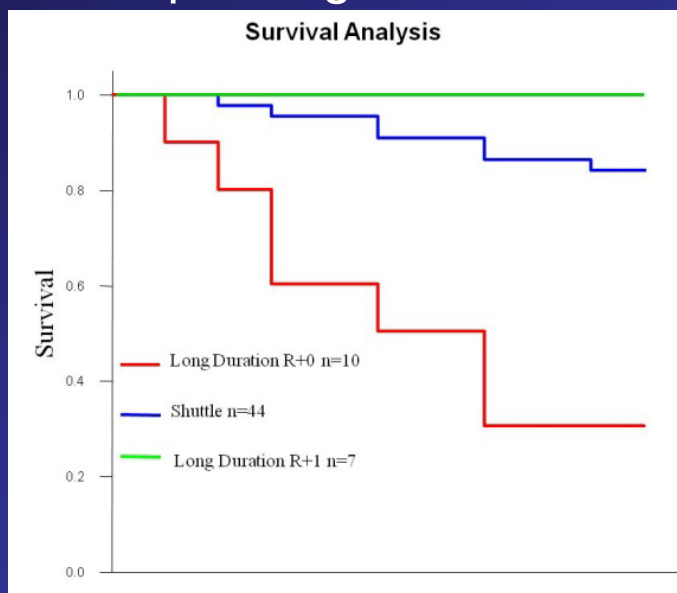
Steven H. Platts<sup>1</sup>, Stuart M.C. Lee<sup>2</sup>, Christian M. Westby<sup>3</sup>, L. Christine Ribeiro<sup>2</sup>, Michael B. Stenger<sup>2</sup>

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# Introduction

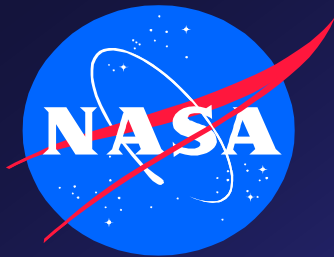
- Orthostatic intolerance has been documented following short and long duration spaceflight



Shuttle vs. Long Duration R+0 =  $p < 0.02$

Long Duration R+0 vs. Long Duration R+1 =  $p < 0.03$

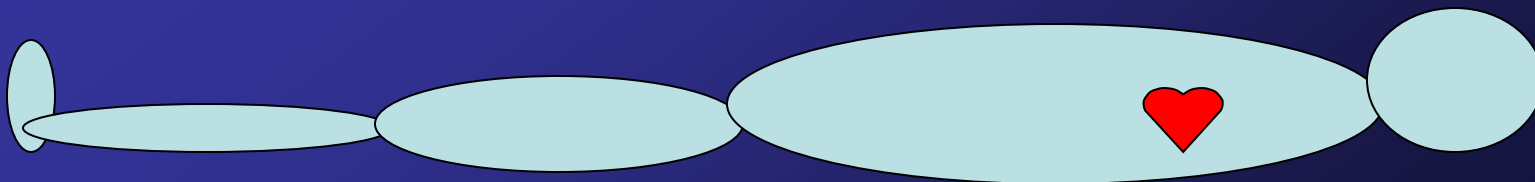
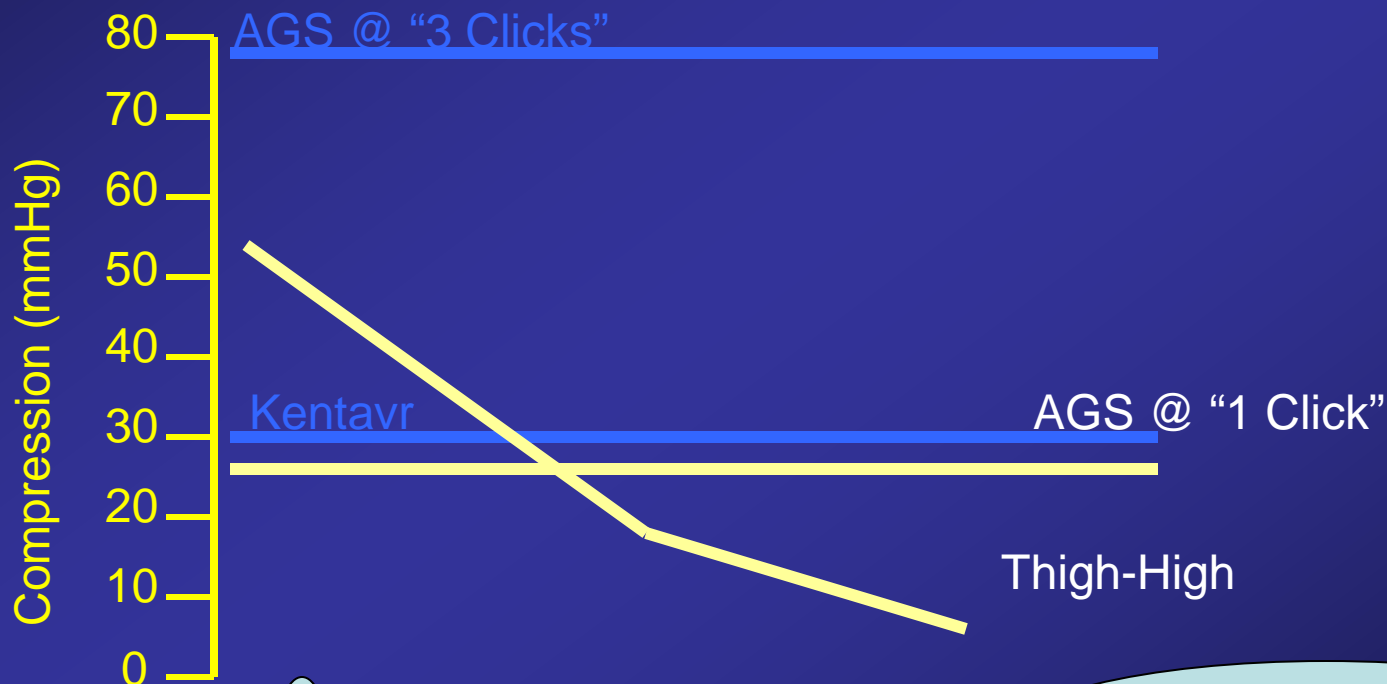
- Several countermeasures have been employed to ameliorate orthostatic intolerance; salt/fluid loading and reentry compression garments.
- The reentry suit (AGS) used during the shuttle era is unlikely to be suitable for future exploration class spaceflights



# Thigh-high compression stockings following short-duration spaceflight

## Commercially available compression stockings

- Gradient Compression
- Calf and Thigh Coverage only

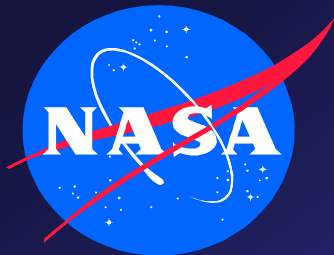


# Thigh-high compression stockings following short-duration spaceflight

	No Countermeasure		Countermeasure	
	Supine	Tilt	Supine	Tilt
SBP (mmHg)	121 ± 4	112 ± 4	136 ± 5	132 ± 5*
DBP (mmHg)	74 ± 2	77 ± 2	77 ± 3	80 ± 3
Heart Rate (bpm)	67 ± 4	89 ± 4	73 ± 6	87 ± 6 <sup>†</sup>
Stroke Volume (ml)	58 ± 4	26 ± 4	73 ± 6	42 ± 6 <sup>*,†</sup>
Cardiac Output (L • min <sup>-1</sup> )	4.0 ± 0.3	2.3 ± 0.3	5.5 ± 0.5	3.7 ± 0.5 <sup>*,†</sup>

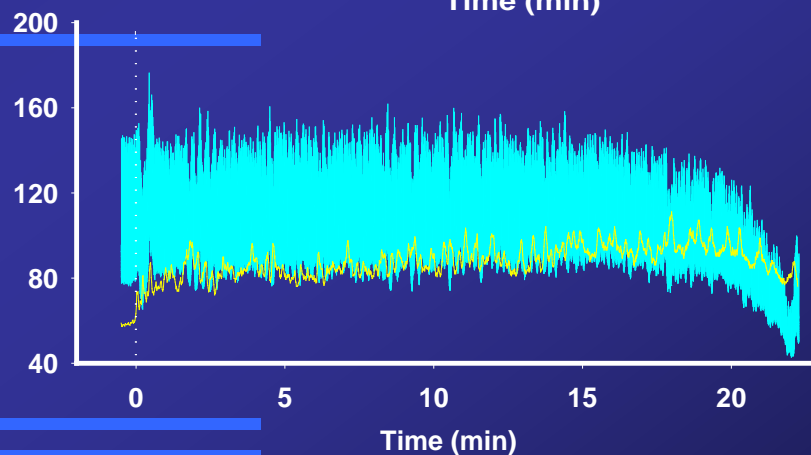
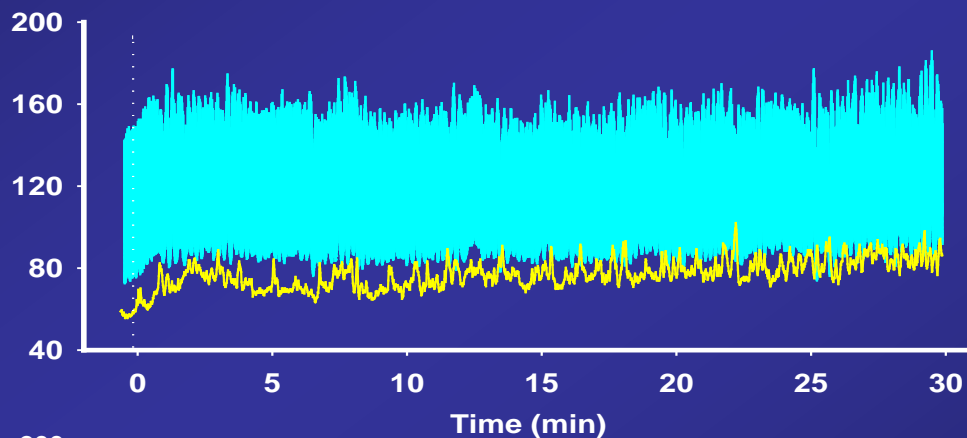
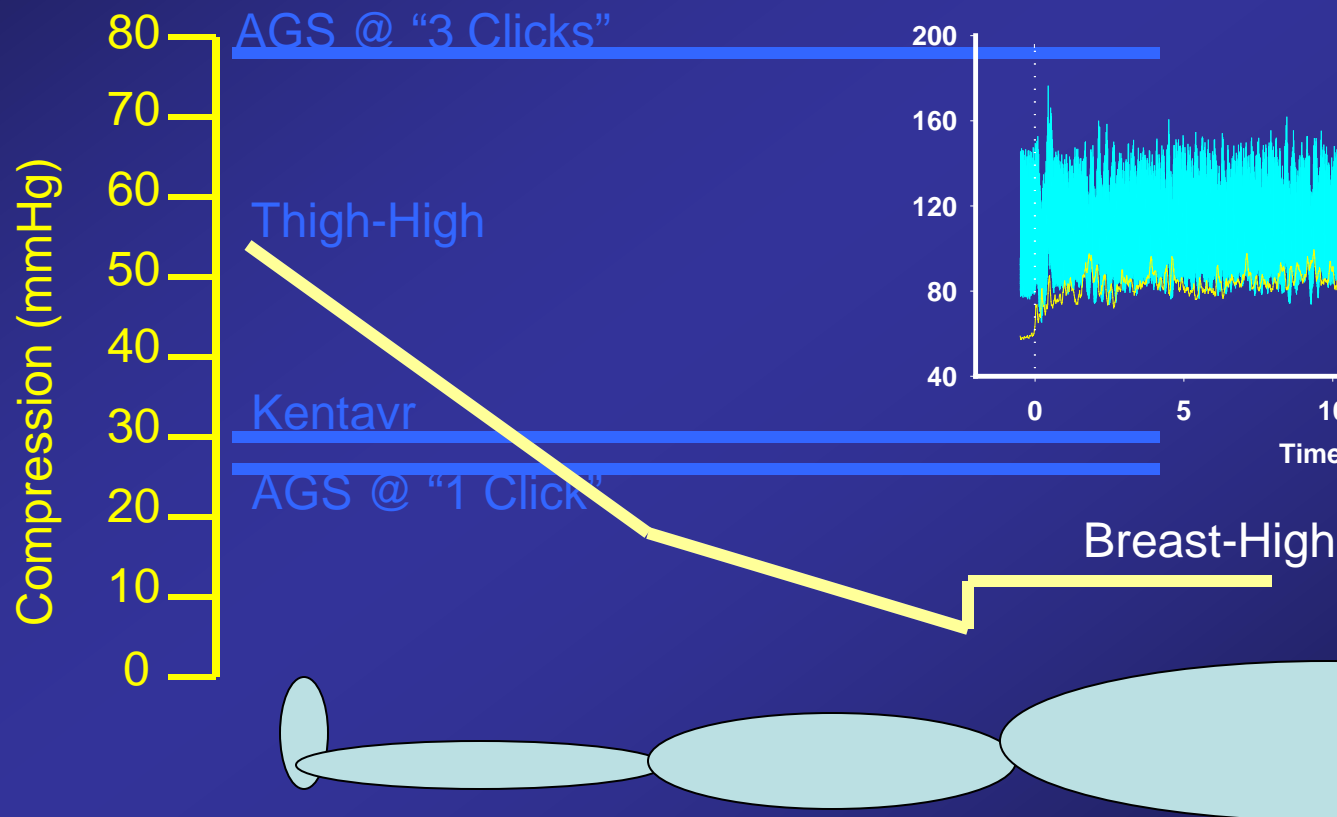
SBP = systolic blood pressure; DBP = diastolic blood pressure.  
 \* Significant difference between non-countermeasure and countermeasure groups (main effect  $P < 0.05$ ).  
 † Significant difference between supine and tilt (main effect  $P < 0.05$ ).

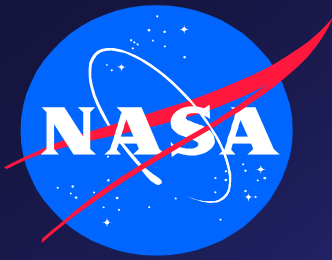
Stenger et al., 2010.



# Breast-High Stockings

During  $G_z$  stress, fluid pools in the splanchnic and calf circulations.





Compression Garment: Thigh-high with “biker” shorts, continuous compression from the feet to the abdomen.

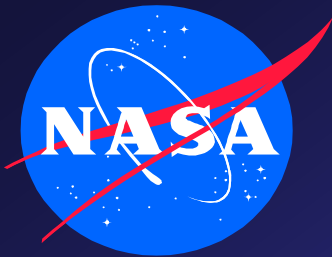


**Abdominal Compression:**  
~ 15 mmHg

**Thigh Compression:**  
~ 20 mmHg

**Ankle Compression:**  
55 mmHg



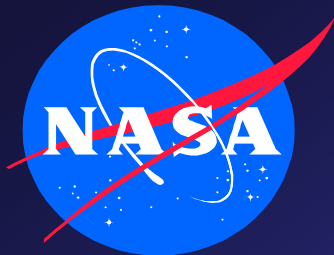


# Study Overview

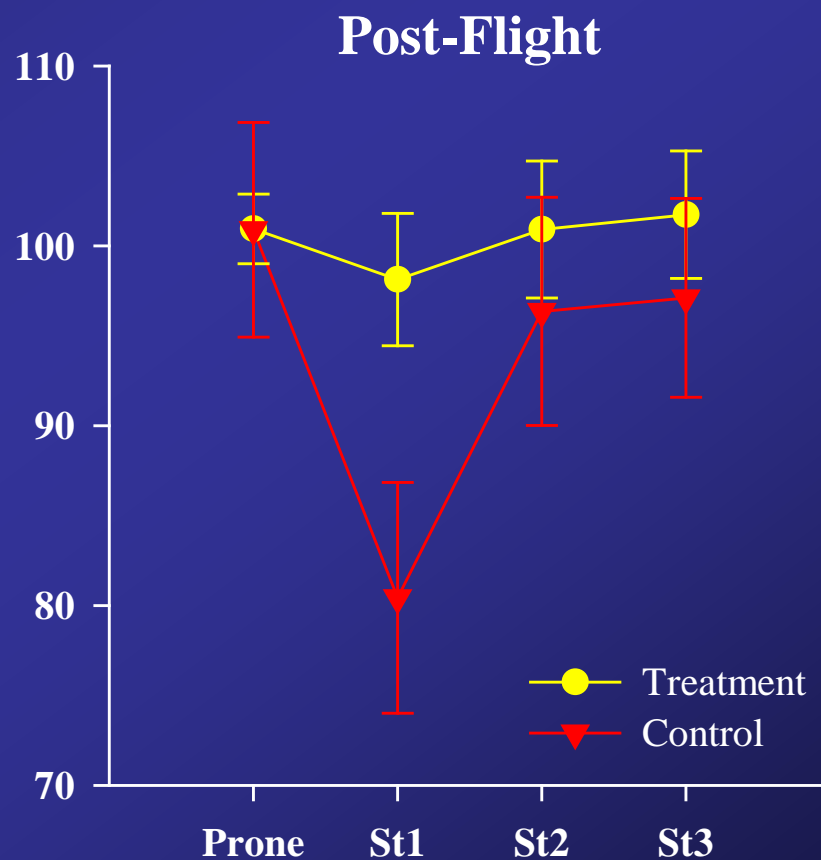
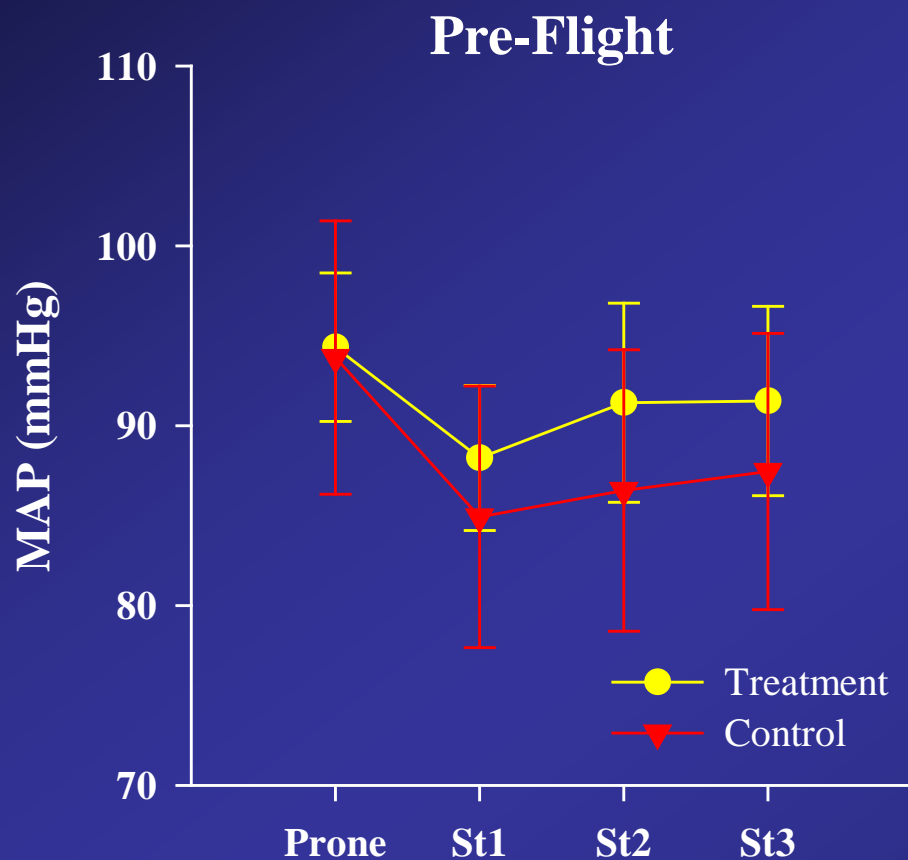
- To test the efficacy of these garments after space flight, we measured cardiovascular responses to quiet standing before and after Space Shuttle missions on landing day and one day after landing.
- Post-flight testing was conducted while subjects wore the compression garments and the results were compared to stand test results from another study (Functional Task Test) in which the subjects are not wearing compression garments.

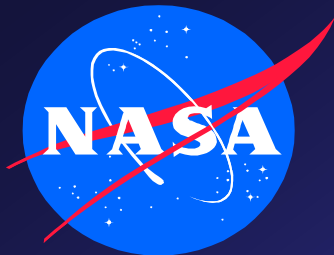


- **Abdomen, thigh, and calf circumference were measured pre- and post-flight to improve fitting of the custom garments for future applications**

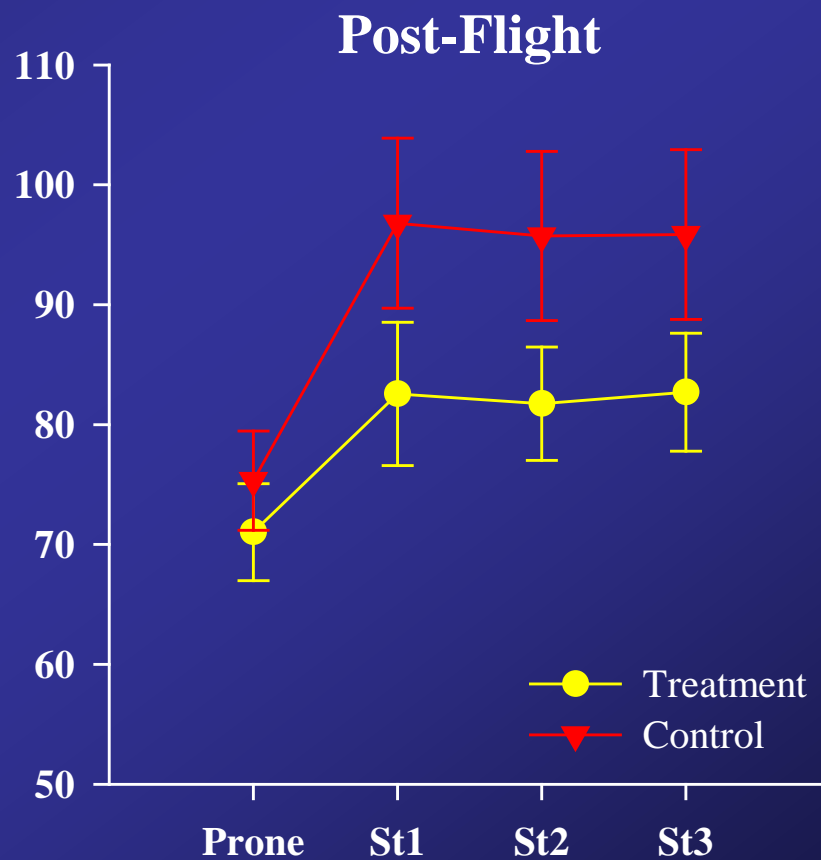
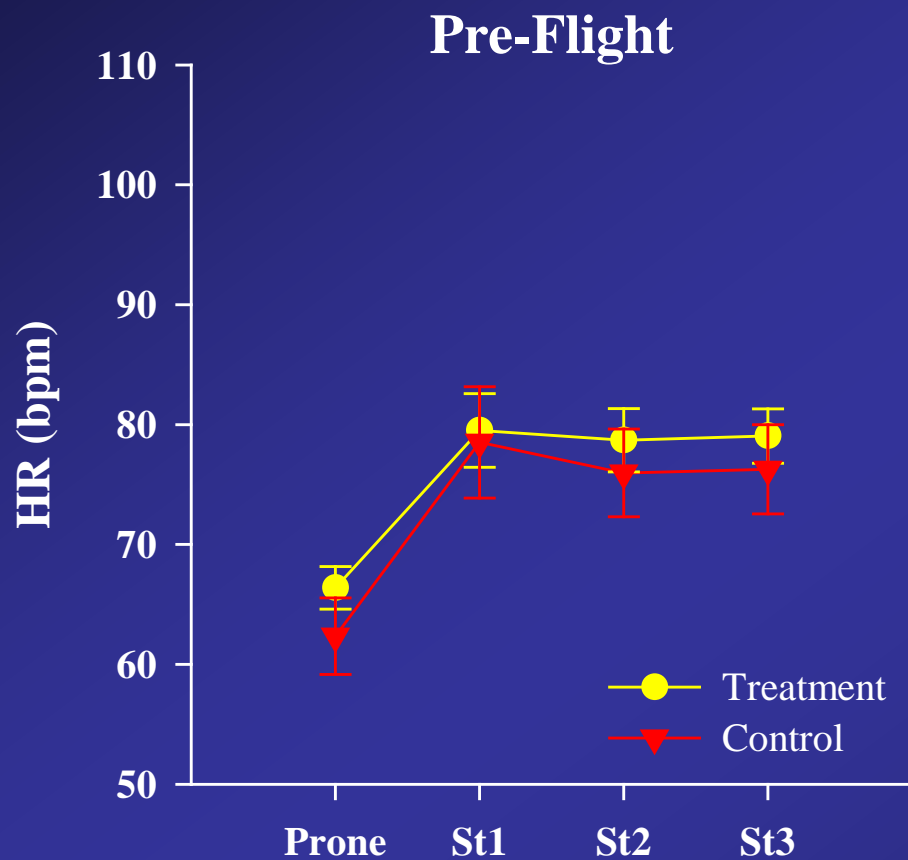


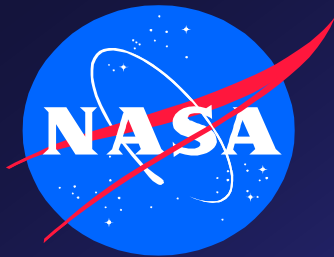
# Effects of compression garments on mean arterial pressure



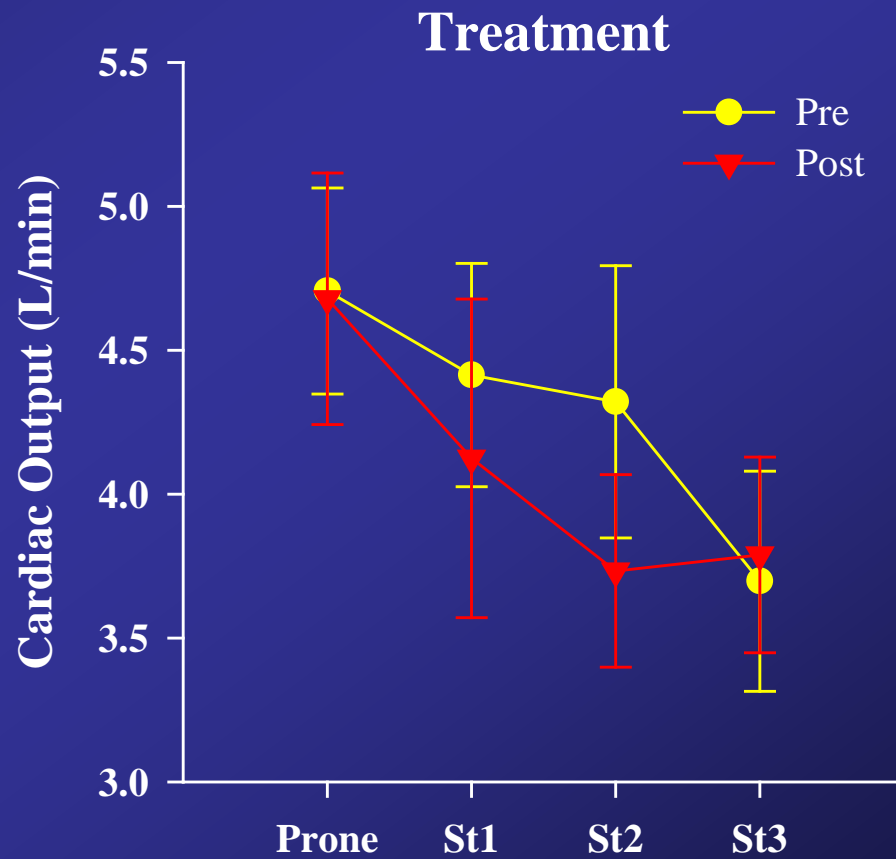
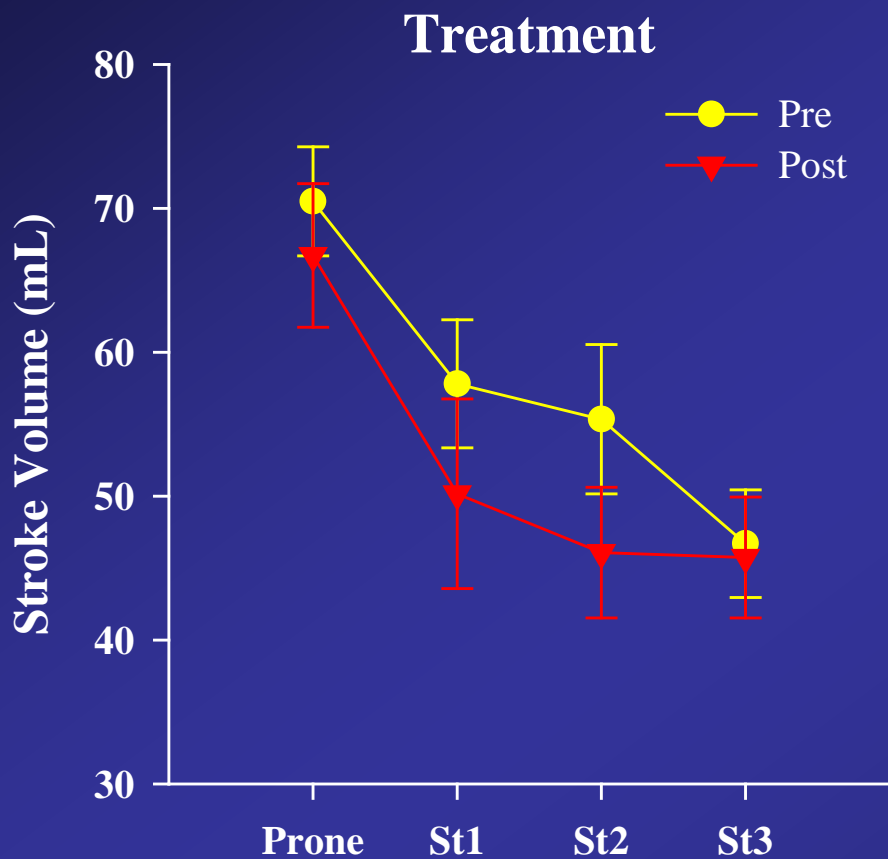


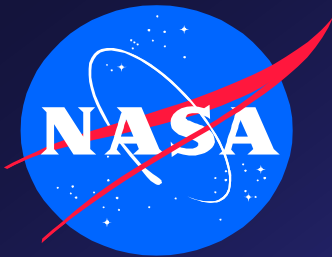
# Effects of compression garments on heart rate



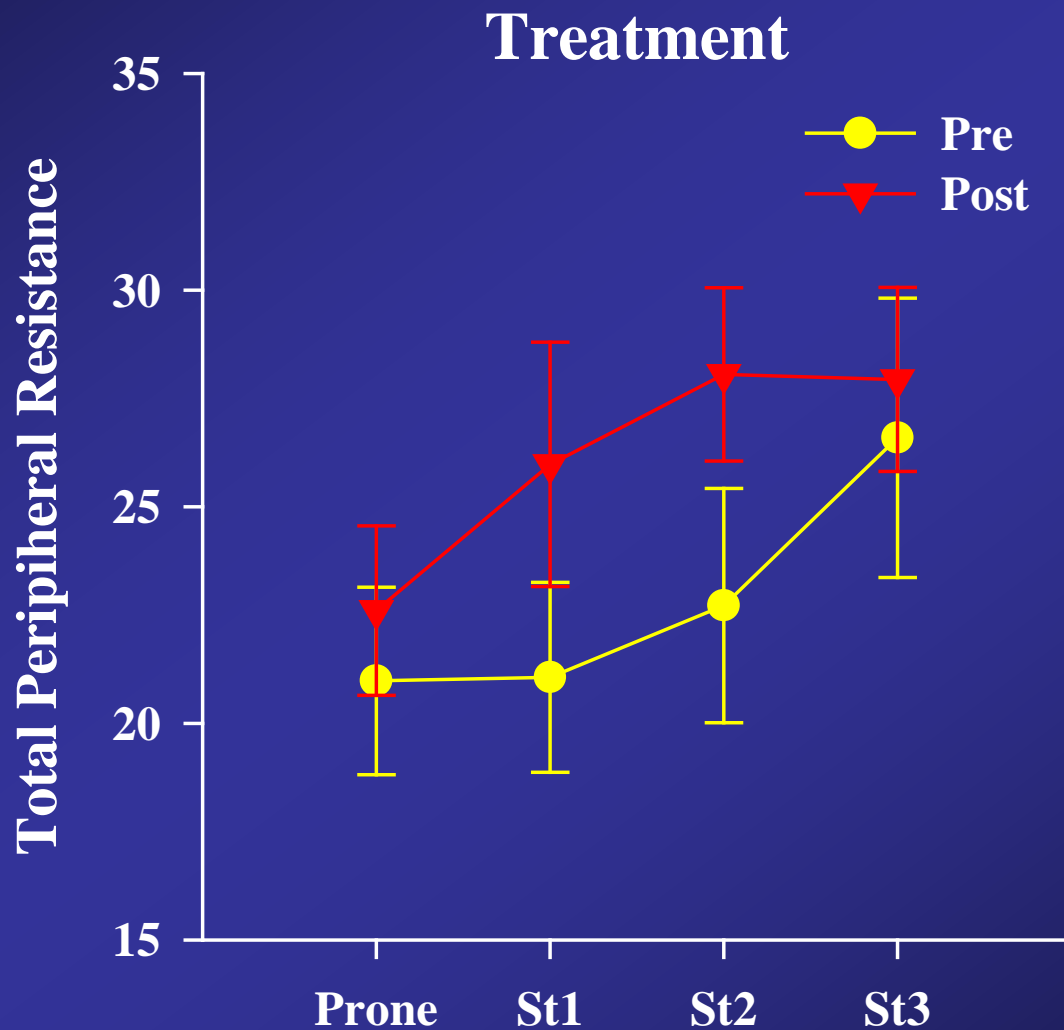


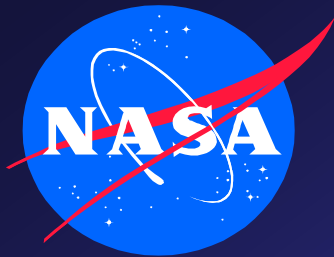
# Effects of compression garments on stroke volume and cardiac output



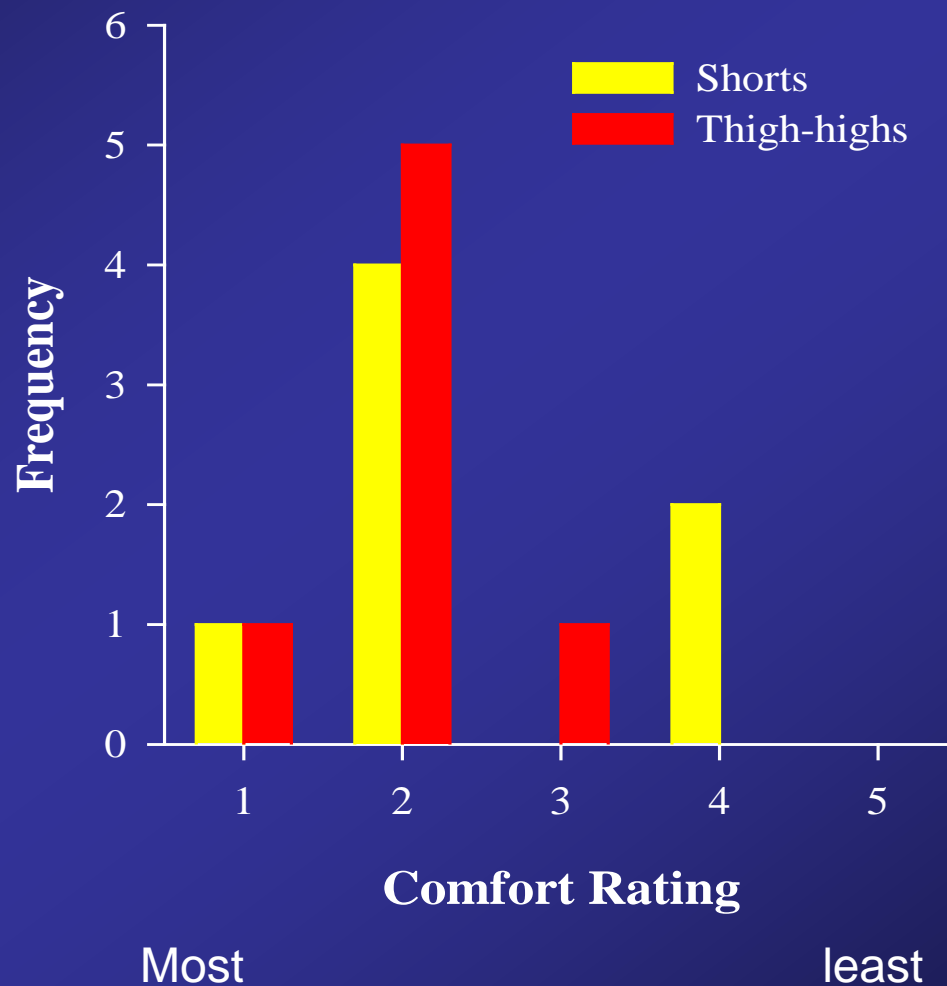


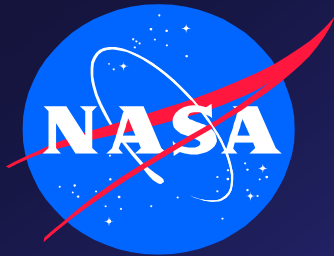
## Effects of compression garments on total peripheral resistance





# Garment subjective comfort ratings





# Conclusions

- **We believe that custom-fitted, commercial compression garments like those tested in our laboratory will protect against orthostatic intolerance immediately after space flight and during recovery.**
- **The benefits of this garment include:**
  - **Graded compression from the foot to the hip with static compression over the abdomen (providing highest compression over areas with highest hydrostatic pressures)**
  - **Complete coverage of the lower body to prevent local swelling**
  - **Fit and comfort of wear demonstrated in clinical populations during long-term use**
  - **Potential use with a variety of mission plans and vehicles.**
- **Information from this study will be used to aid in development of future compression garments for re-entry and landing as well as during recovery.**