

# Effect of Spaceflight on Cardiovascular Responses to Upright Posture in a 77-Year-Old Astronaut

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**D**uring spaceflight the cardiovascular system undergoes changes that result consistently in orthostatic hypotension and syncope or presyncope after landing. Recently, we were afforded the opportunity to document cardiovascular responses to standing before and after a 10-day spaceflight in a 77-year-old man and compared them with responses previously documented in younger male astronauts. The study was approved by the Johnson Space Center Investigational Review Board. Data were collected 10 days before launch, 2 hours after landing, and 3 days after landing. Before each test, the subject abstained from caffeine, alcohol, and any medication for the preceding 12 hours, was  $\geq 2$  hours postprandial, and had not exercised heavily in 24 hours. The subject was laid on a tilt table, and instrumented for electrocardiogram, manual blood pressure (sphygmomanometer), and finger arterial pressure (Finapres, Ohmeda, Inglewood, Colorado). A catheter was inserted into an antecubital vein. After a 20-minute supine period, a blood sample was drawn for determination of plasma norepinephrine and epinephrine levels. Plasma volume was determined using carbon monoxide rebreathing.<sup>1</sup> Two-dimensional and M-mode echocardiography were used to determine aortic cross-sectional diameter and Doppler ultrasound was used to measure beat-to-beat aortic flows. The hand to which the Finapres was attached was strapped to an arm board so that it would remain at heart level in both the supine and

upright positions. Continuous baseline measurements were made for 5 minutes in the supine position and continued while the tilt table was raised to 80° upright. The subject was kept in the upright position for 10 minutes, after which a final blood sample was drawn for plasma norepinephrine and epinephrine levels. Echocardiographic images were recorded on videotape and analog data were recorded on digital tape and paper recorders for later analyses.

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The following variables were compared during the last minute in the supine position and the last minute standing: plasma norepinephrine and epinephrine levels, heart rate, systolic and diastolic pressures, stroke volume, cardiac output (stroke volume  $\times$  heart rate), and total peripheral resistance (mean arterial pressure/cardiac output). Analyses of all signals were made by using standard data acquisition and analysis packages. Plasma norepinephrine and epinephrine levels were determined using a radioenzymatic assay.<sup>2</sup>

No statistical analyses were performed on the data from the elderly subject. Because the subject did not become presyncopal during tilt testing on any of the test days, his data were compared with those of 20 younger male astronauts ( $41 \pm 1$  years of age) who had previously participated in the same study<sup>3</sup> and who also did not become presyncopal. Data from the younger astronauts are presented as mean  $\pm$  SEM.

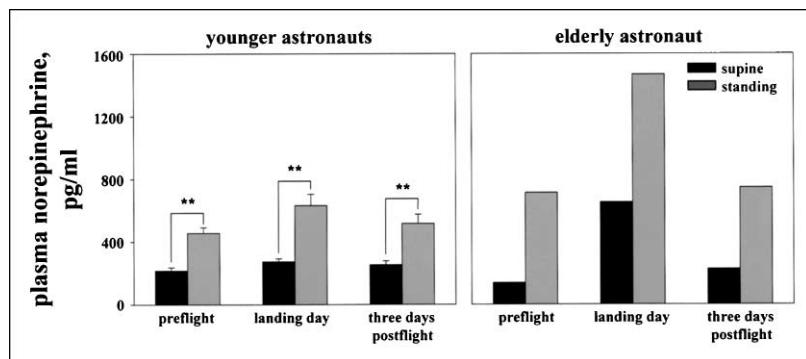
Female astronauts who had previously participated in this study were excluded based on the known gender differences in response to orthostatic stress as well as their greater susceptibility to orthostatic hypotension after spaceflight.<sup>3</sup>

Plasma volumes were reduced about 6% from preflight to landing day in the younger astronauts, from

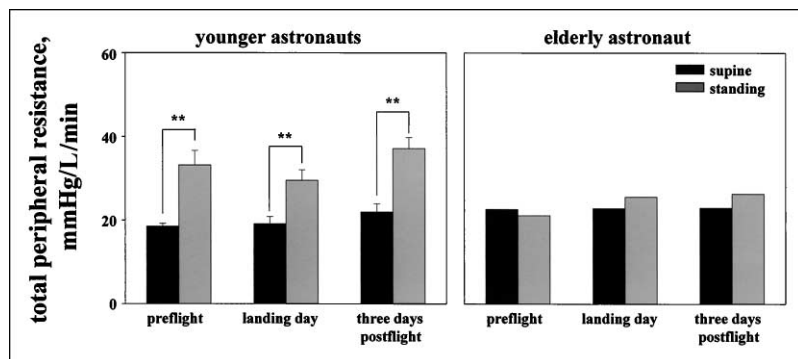
$3.44 \pm 0.13$  to  $3.23 \pm 0.16$  liters. The elderly astronaut had no reduction in plasma volume (3.51 liters preflight, 3.65 liters on landing day).

Supine and standing mean arterial pressures were similar between the younger and older astronauts on all occasions. In the younger group, supine pressure was  $88 \pm 1$  mm Hg preflight,  $92 \pm 2$  mm Hg on landing day, and  $91 \pm 1$  mm Hg 3 days after landing. Standing pressures were  $89 \pm 2$ ,  $90 \pm 2$ , and  $92 \pm 2$  mm Hg, respectively. The supine pressures in the elderly subject were 86 mm Hg preflight, 97 mm Hg on landing day, and 92 mm Hg 3 days after landing. His standing pressures were 89, 104, and 93 mm Hg, respectively. The elderly subject, however, had a hemodynamic profile that was very different from the younger subjects. There were several notable differences in his responses to standing. First, the elderly subject demonstrated greater increases in norepinephrine levels upon standing than his younger counterparts, most particularly on landing day (Figure 1). Second, the elderly subject had lower epinephrine levels on all occasions than the younger astronauts. Supine plasma epinephrine levels for the younger men were  $19 \pm 3$  pg/ml preflight,  $24 \pm 2$  pg/ml on landing day, and  $24 \pm 4$  pg/ml 3 days after landing. Their standing levels were  $37 \pm 4$ ,  $50 \pm 7$ , and  $37 \pm 3$  pg/ml, respectively. Supine epinephrine levels for the elderly subject were 15 pg/ml preflight, 18 pg/ml on landing day, and 9 pg/ml 3 days after landing. His standing levels were 4, 16, and 15 pg/ml, respectively. The third and fourth differences were that, despite his seemingly high sympathetic activation, the elderly subject showed virtually no increase in total peripheral resistance (Figure 2), and minimal increases in heart rate (Figure 3), with standing during all

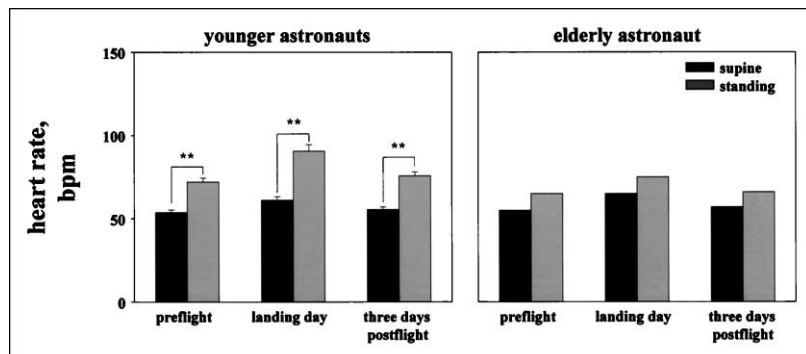
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**FIGURE 1.** Plasma norepinephrine levels in the supine position and at standing before flight, on landing day, and 3 days after landing in 20 younger astronauts and 1 elderly astronaut. The elderly astronaut had extraordinarily high levels of norepinephrine on landing day. \*\* $p < 0.001$ .



**FIGURE 2.** Total peripheral resistance in the supine position and at standing before flight, on landing day, and 3 days after landing in 20 younger astronauts and 1 elderly astronaut. Although the younger astronauts had significant increases in resistance with standing on all occasions, the elderly astronaut had very small changes in resistance. \*\* $p < 0.001$ .



**FIGURE 3.** Heart rates in the supine position and at standing before flight, on landing day, and 3 days after landing in 20 younger astronauts and 1 elderly astronaut. Although the younger astronauts showed significant increases in heart rate with standing on all occasions, the elderly astronaut had only small increases in heart rate. \*\* $p < 0.001$ .

test sessions. In contrast, the younger astronauts had significant increases in resistance and heart rate upon standing. Finally, during all test sessions, the elderly astronaut maintained upright stroke volume close to his supine levels, whereas the younger astronauts al-

ways had significant decreases in standing stroke volumes (Figure 4).

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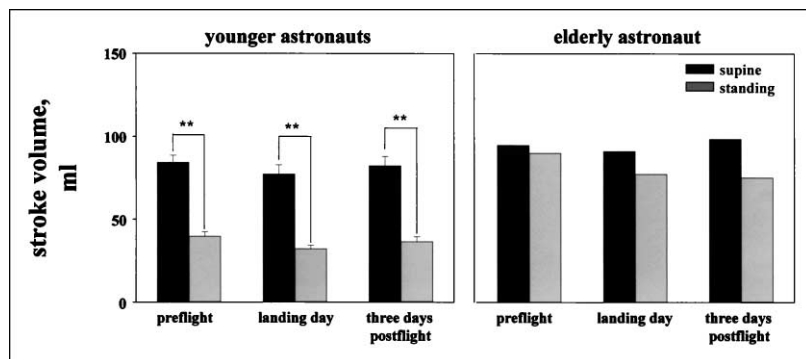
Previous studies have documented important individual differences in the effects of spaceflight on astronauts. Those who become presyncopal during upright posture after

landing consistently have shown low standing total peripheral resistance<sup>3,4</sup> and plasma norepinephrine levels.<sup>3,5</sup> In contrast, astronauts who do not become presyncopal on landing day have hyperadrenergic responses,<sup>3,6</sup> which adequately increase standing peripheral resistance. In the present study, the elderly male astronaut did not become presyncopal. Therefore, we chose to compare his data only to data from a group of younger male astronauts who also had not become presyncopal, thus eliminating gender as a factor. This comparison revealed important differences between the older and younger men.

A striking finding from this study was the dramatic increase in norepinephrine levels at standing in the elderly subject on landing day, which was greater than that of any other subject. This seems to be consistent with his age. Aging is associated with high plasma norepinephrine levels at rest,<sup>7-9</sup> in response to mental stress,<sup>10</sup> exercise,<sup>11,12</sup> and upright posture. Epinephrine levels have not been shown to increase with aging,<sup>13</sup> which is also consistent with the present findings.

The high plasma norepinephrine levels at standing in the elderly subject did not translate into substantial increases in either heart rate or total peripheral resistance. This pattern persisted during every test session and is consistent with reports in the literature of reductions in inotropic and chronotropic responses in the elderly.<sup>9,14</sup> Both the low cardiac and resistance responses are probably due to age-associated changes in adrenergic receptor function.<sup>15-17</sup>

Stroke volume at standing was maintained in the older astronaut during all test sessions, and seemed to be the key factor in his ability to maintain upright pressure. It has been shown that stroke volume is maintained better in elderly men than in young men during stand tests.<sup>18</sup> Furthermore, during exercise, cardiac output is maintained with a lower heart rate, higher end-diastolic volume, and higher stroke volume in elderly versus younger subjects.<sup>19</sup>



**FIGURE 4.** Stroke volumes in the supine position and at standing before flight, on landing day, and 3 days after landing in 20 younger astronauts and 1 elderly astronaut. The younger astronauts had significantly smaller stroke volumes at standing than while supine on all occasions. In contrast, the elderly astronaut had very little loss of stroke volume with standing. \*\* $p < 0.001$ .

In summary, a 77-year-old male astronaut underwent tilt tests before and after spaceflight and did not become presyncopal during any test session. He experienced arterial pressures that were very similar to those of younger astronauts. However, the hemodynamic strategies he employed were very different from the younger astronauts, but typical of those in older populations. His responses were not deleteriously affected by spaceflight. This subject's excellent physical condition allowed him to endure the rigors of spaceflight, but did not allow him to escape all the physiologic effects of aging. These data suggest that elderly individuals who maintain their health and fitness are able to withstand the stresses of extreme

environments and do not necessarily need to limit their activities simply due to their chronological age.

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