Submacular Choroid Thickness Increases During Long-Duration Spaceflight

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BACKGROUND

- The Spaceflight Associated Neuro-ocular Syndrome (SANS) is characterized by the development of optic disc edema, choroidal folds, cotton-wool spots, globe flattening, and/or refractive error changes ≥0.75D during long-duration spaceflight to the International Space Station (ISS)[1]. The number of astronauts with each finding is shown in Figure 1.

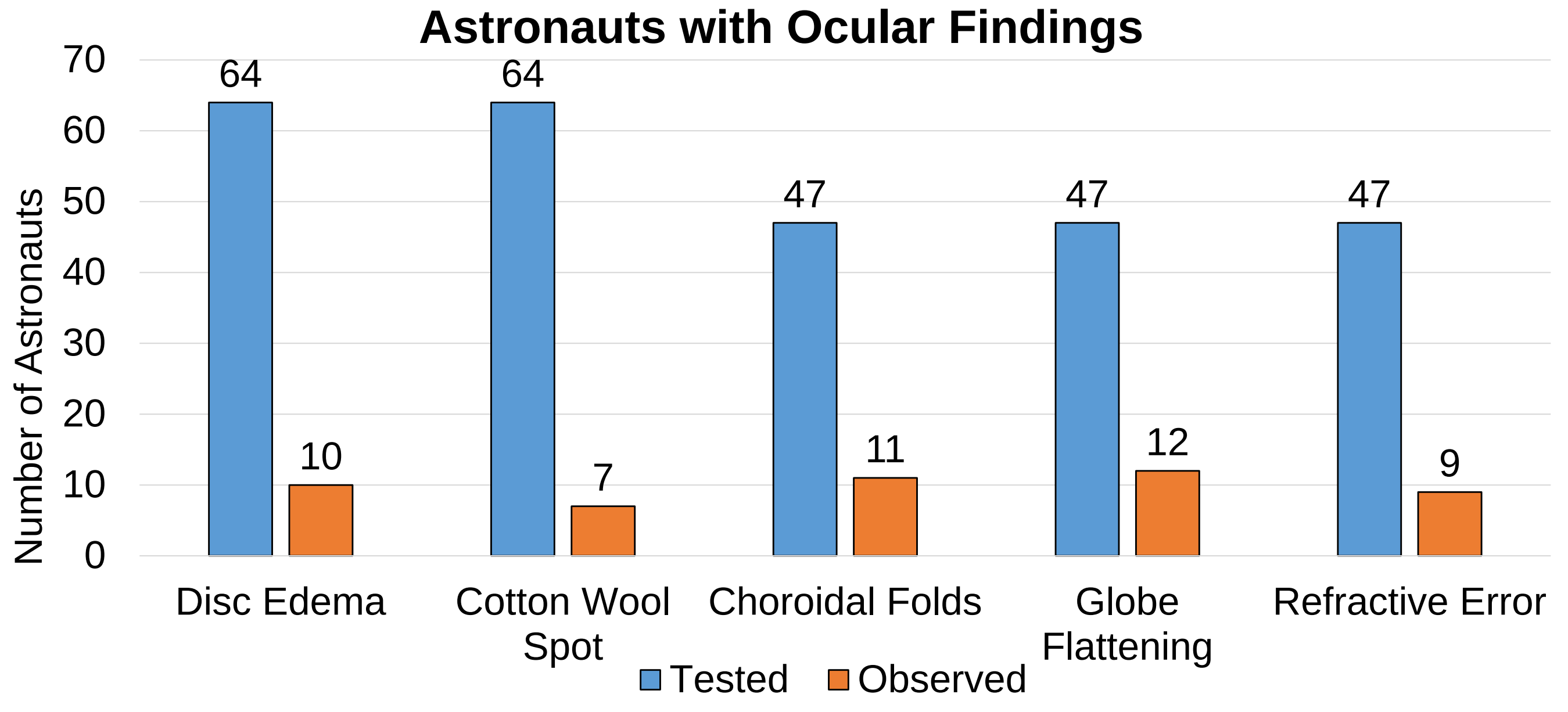


Figure 1. Ophthalmic findings in astronauts following long-duration spaceflight.

- It is hypothesized that these findings result from the headward fluid shift that occurs due to weightlessness.
- We can induce a headward fluid shift on Earth using positional changes and on ISS due to weightlessness.
- Lower-body negative pressure (LBNP) is used to reverse the headward fluid shift by drawing fluid into the lower body and can be used on Earth and on ISS.

PURPOSE

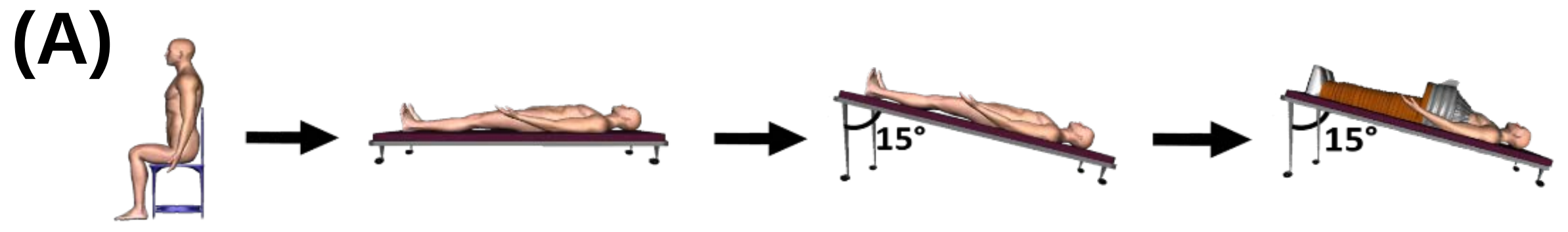
The purpose of this experiment was to characterize how the headward fluid shift during spaceflight affects choroid thickness (CT) and intraocular pressure (IOP) and to determine if use of LBNP could reverse the effects of the headward fluid shift on these variables.

METHODS

- Nine astronauts were studied before, during, and after long-duration spaceflight on the ISS (Figure 2).
- Heidelberg Spectralis OCT was used to obtain a single B-scan through the macula and optic disc on Earth and on ISS (Figures 2 and 3).
- During spaceflight, data collection occurred in weightlessness (Spaceflight, SF) and during activation of LBNP (SF + LBNP).
- IOP was measured using Icare Pro (on Earth) and TonoPen Avia (ISS).
- Mixed-effects linear regression modeling was used to derive means and 95% confidence intervals (Stata/IC 14.2).

METHODS

Preflight and Postflight Testing



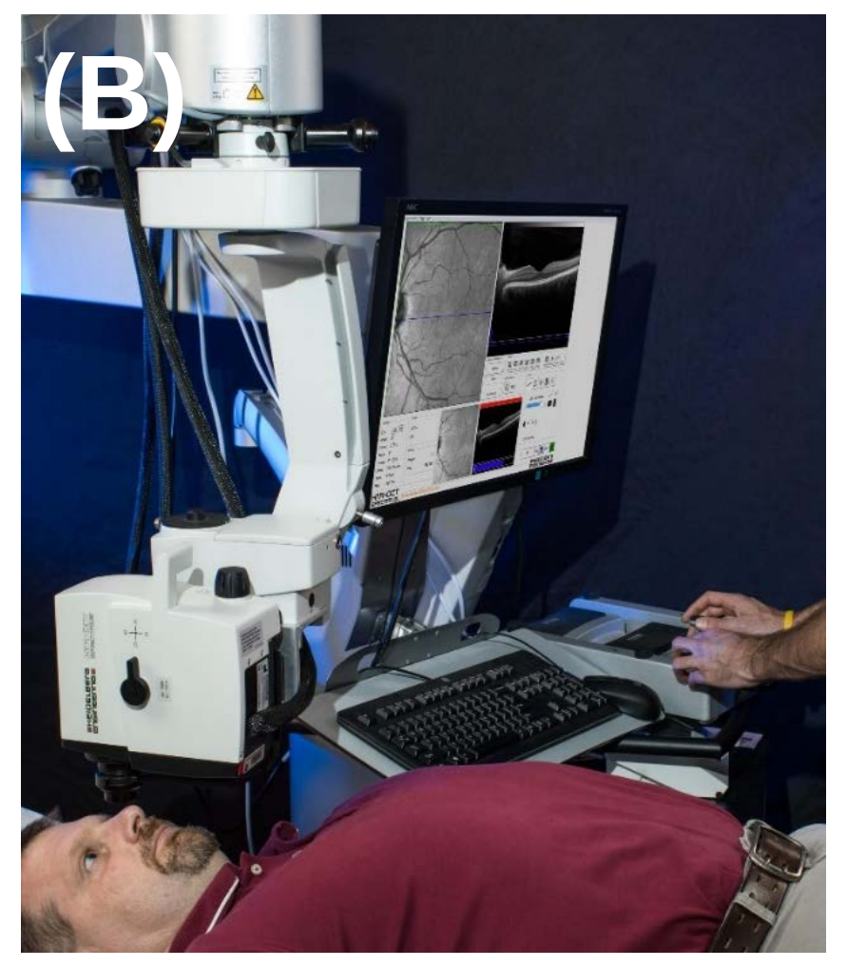
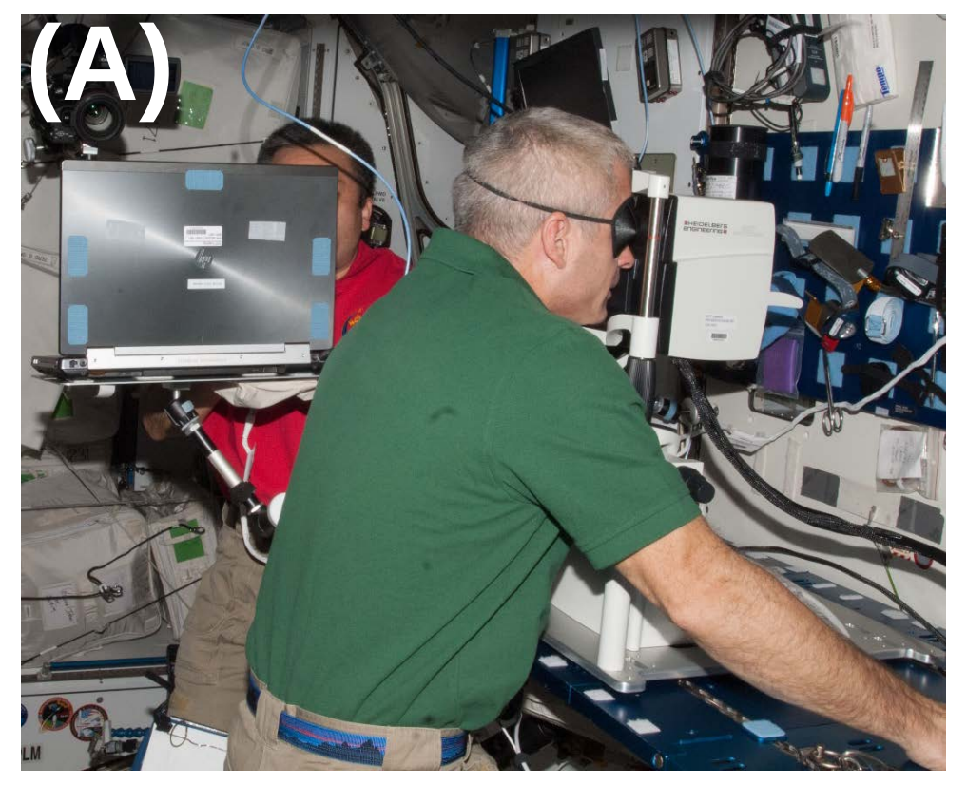
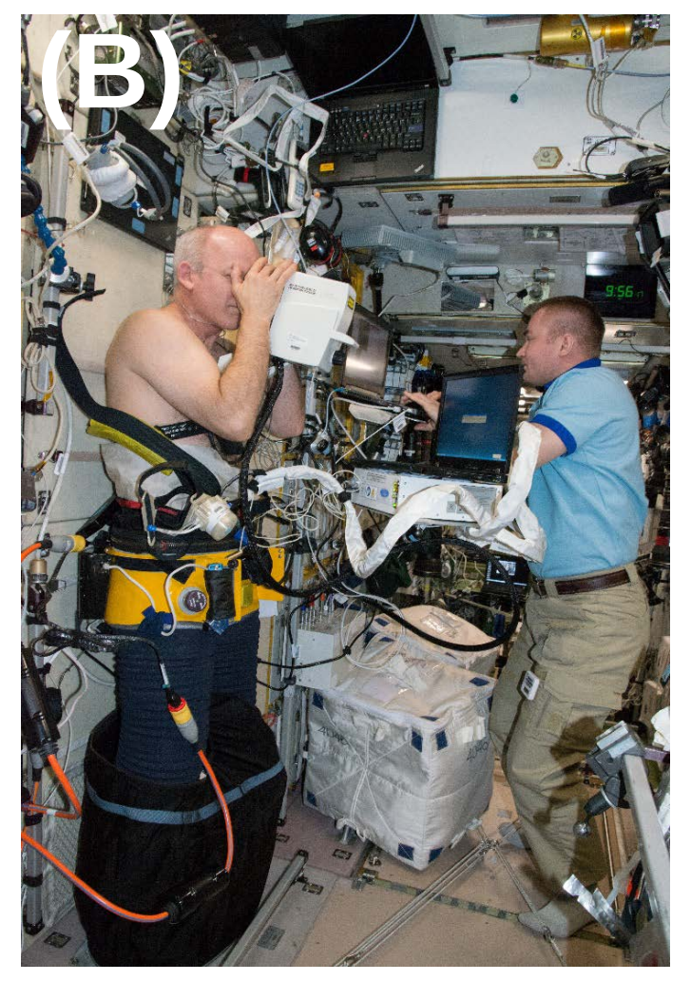


Figure 2. (A) On Earth, astronauts were studied preflight while seated, supine, 15° head-down tilt (HDT), and HDT with LBNP (Chibis). **(B)** The OCT camera was mounted on a surgical arm to allow imaging in all postures.

Spaceflight Testing





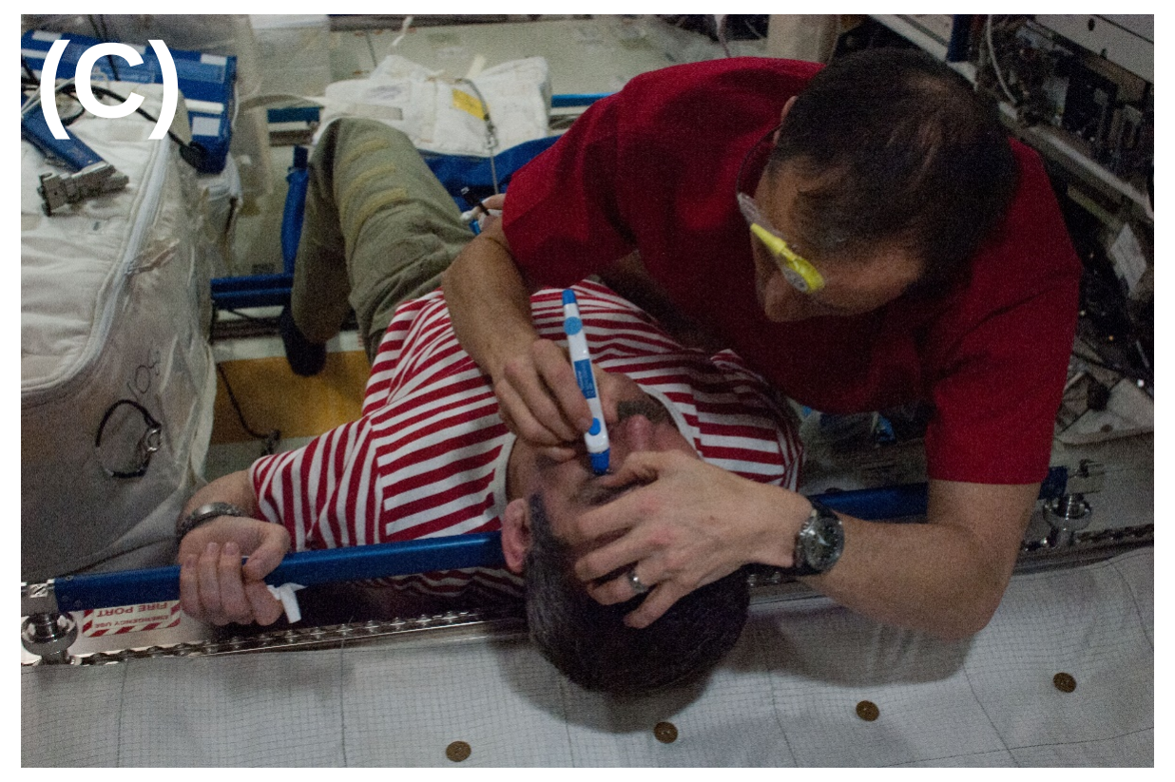


Figure 3. On ISS OCT images and IOP measurements were acquired through remote guidance by ground experts. **(A)** During regular spaceflight operations the OCT camera was used in a nominal configuration with the chinrest. **(B)** During use of LBNP the camera was removed from the chinrest and held by the astronaut. **(C)** IOP was measured in triplicate using tonometry (TonoPen Avia).

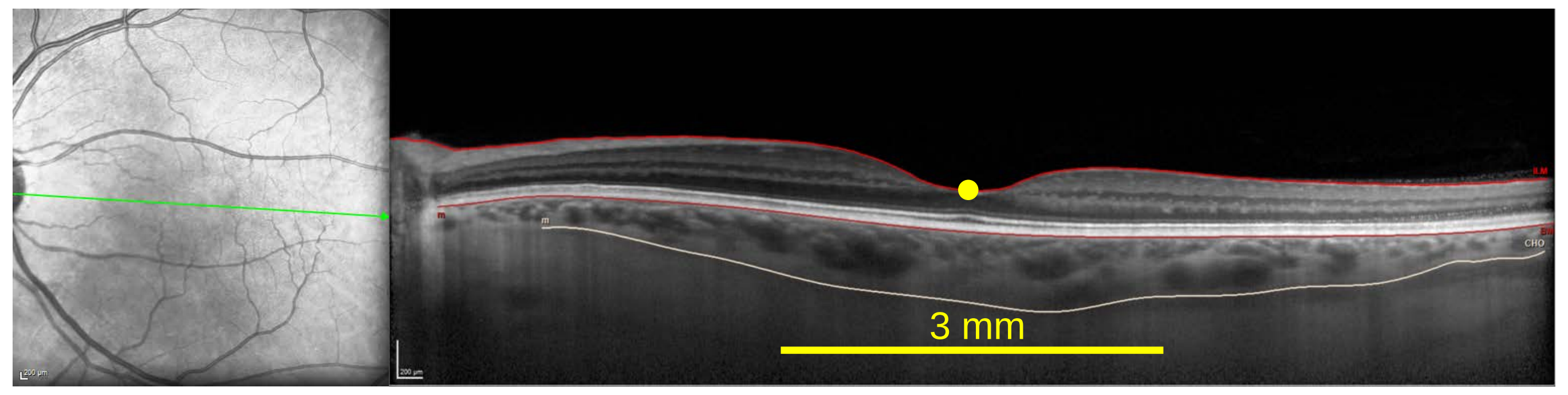


Figure 4. The B-scan was centered through the fovea and optic nerve head. Bruch's membrane was automatically segmented using Heidelberg Heyex software. The choroid-scleral border was manually segmented by 2 independent observers. The thickness of a 3-mm region centered under the fovea was calculated from the two observations (<10% difference) and used for analysis.

RESULTS

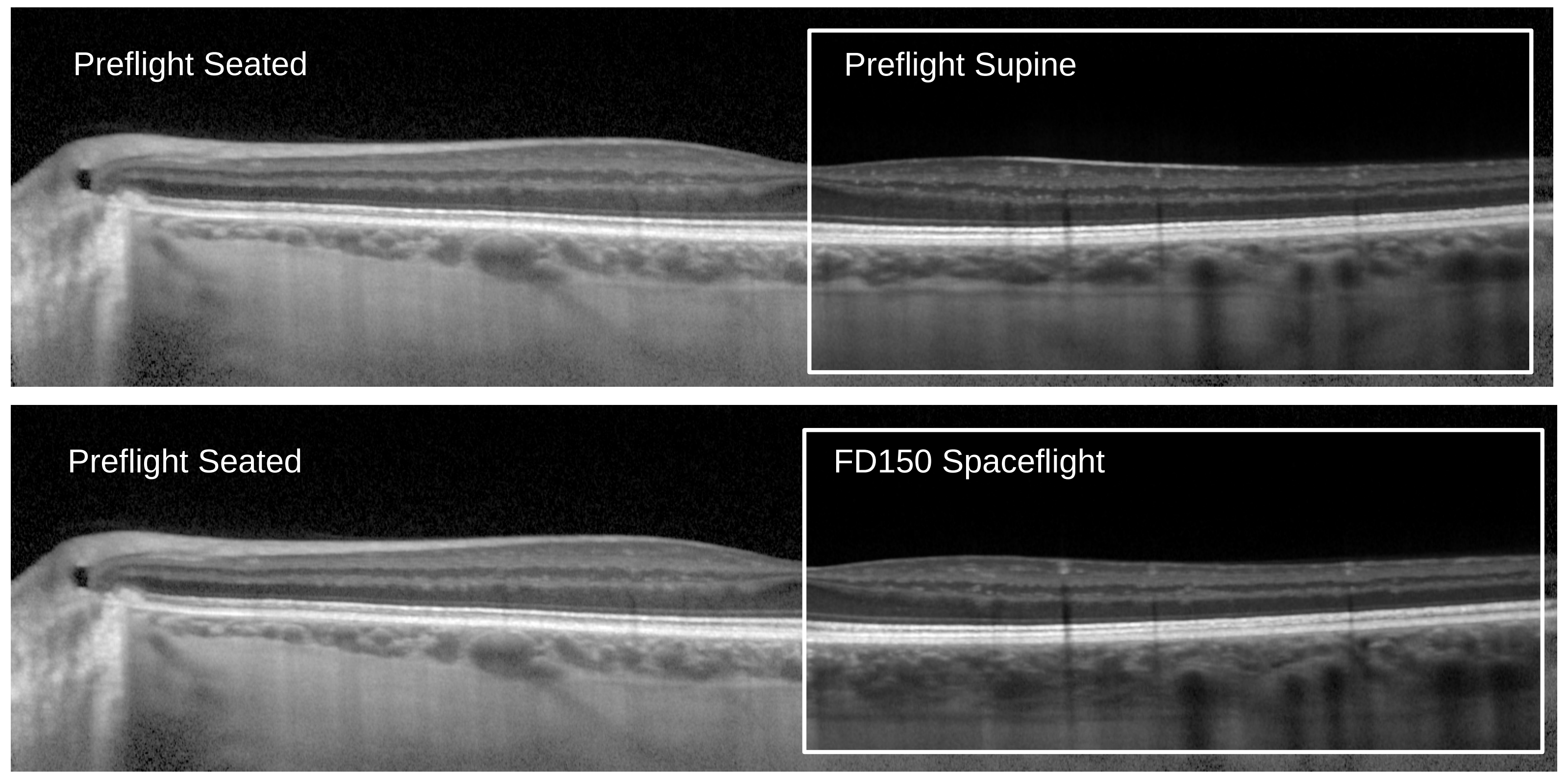


Figure 5. Representative OCT images from a single subject comparing preflight seated image to supine (top) and comparing to an image obtained 116 days into spaceflight (FD150, bottom). The change in submacular choroid thickness between Seated and FD150 in this subject is 93 µm.

RESULTS

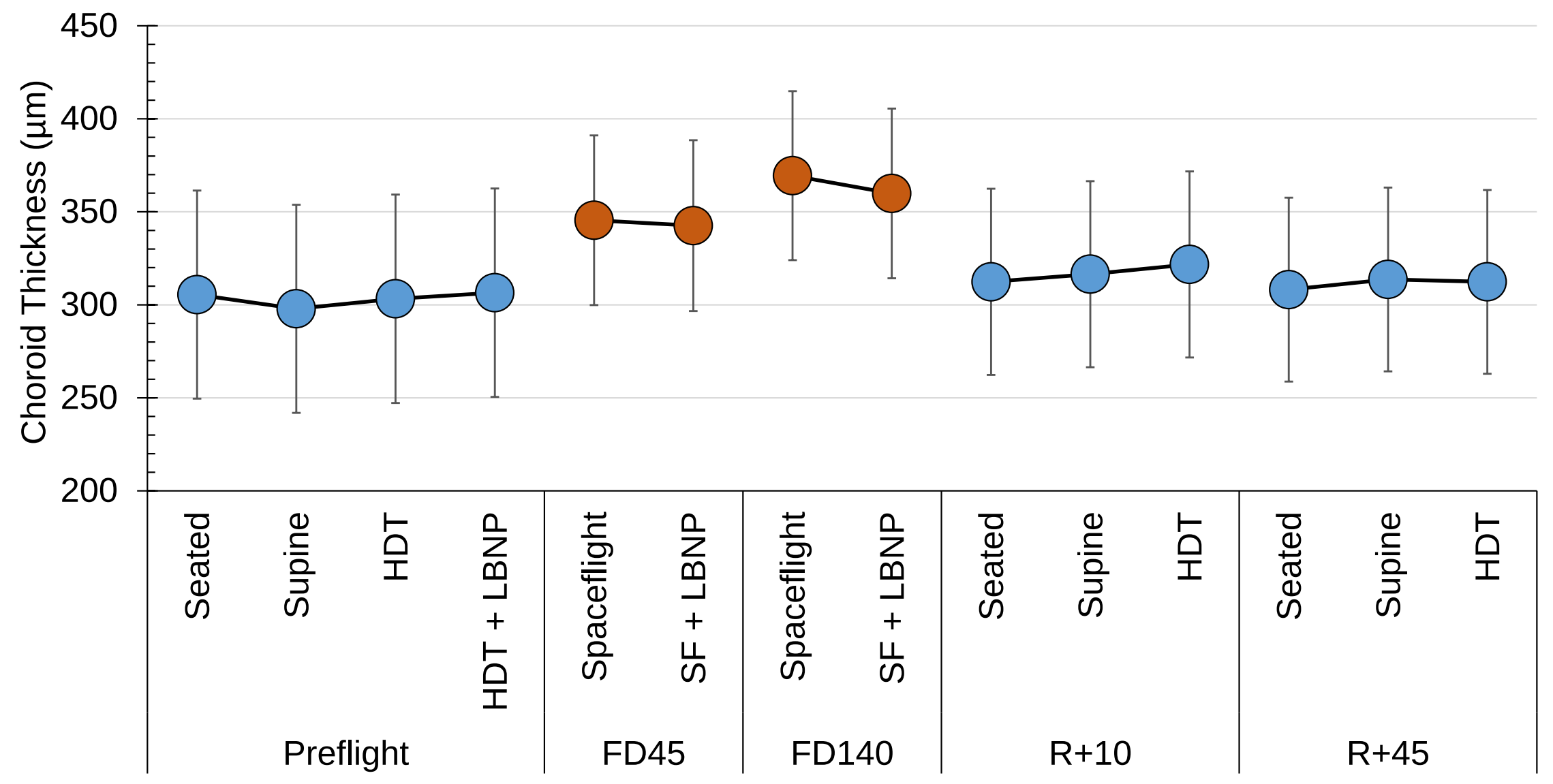


Figure 6. Subfoveal choroid thickness for all subjects before, during, and after spaceflight. Spaceflight values are indicated in orange and are significantly greater than preflight or postflight values. There were no differences between positions during preflight, inflight, or postflight.
FD, flight day; R+, days following return from spaceflight. SF + LBNP, Spaceflight with lower body negative pressure.

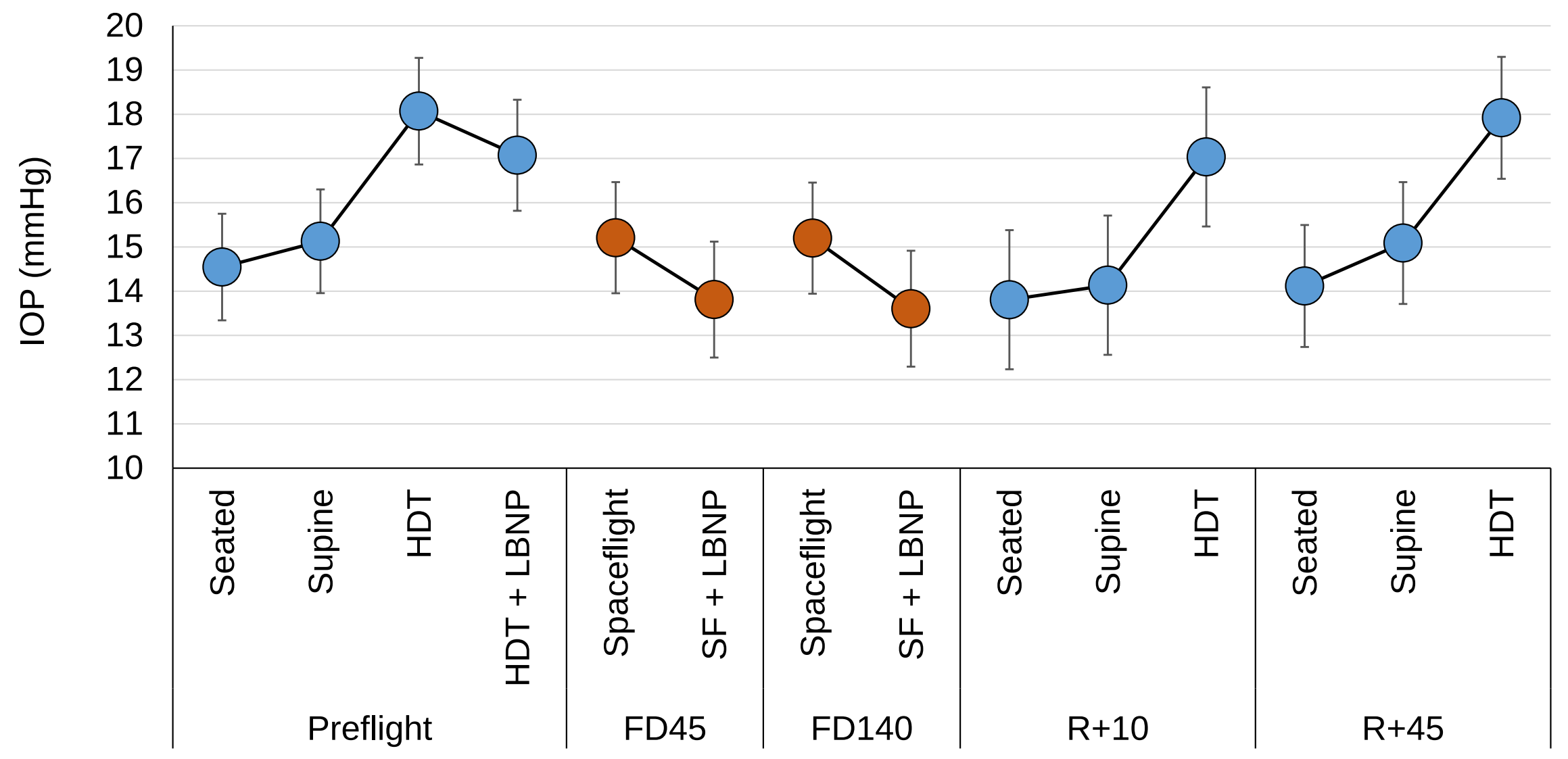


Figure 7. IOP for all subjects before, during, and after spaceflight. Spaceflight values are indicated in orange. IOP during HDT was significantly greater than Seated at all days . Values during spaceflight were not significantly different from Preflight Seated or Supine values.
FD, flight day; R+, days following return from spaceflight. SF + LBNP, Spaceflight with lower body negative pressure.

DISCUSSION

- Acute posture changes on Earth do not cause a significant change in subfoveal choroid thickness.
- Prolonged exposure to weightlessness during spaceflight causes an increase in subfoveal choroid thickness that is not reversed by use of LBNP.
- Following return to Earth (R+10 and R+45), choroid thickness is similar to Preflight values.
- IOP increases during HDT on Earth, but IOP during spaceflight is similar to values measured while supine on Earth. This suggests the known increase in IOP during the first few days of spaceflight[2] resolves and is maintained throughout long-duration flight.
- These data suggest the increase in choroid thickness during spaceflight does not lead to an increase in IOP.
- Whether changes in choroid thickness during spaceflight contribute to, or result from, SANS symptoms such as optic disc edema requires further investigation.

1. Mader TH, *et al*. Optic disc edema, globe flattening, choroidal folds, and hyperopic shifts observed in astronauts after long-duration space flight. *Ophthalmology*. 2011 118:2058-69.
2. Draeger J, *et al. Self-tonometry under microgravity conditions*. Aviat Space Environ Med. 1995 66:568-570.

Disclosures: None

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