The main analysis goal was to separate effects of spaceflight from those of just being in the astronaut corps on the distribution of HNP. In addition, risk direction and of missions, as well as changing criteria for astronaut selection since the pre- Shuttle era. Also, HNP time of incidence was recorded at the time of diagnosis, not at the time of occurrence. Because the data span the entire Astronaut Corps, effects from improved spaceflight deconditioning countermeasures may obscure the risk of developing an HNP, particularly related to landing length. A majority of the long-duration missions occurred in the past 20 years, when countermeasures have been implemented. In addition, the relatively low numbers of long-duration flights and female astronauts adversely affects the power of tests for these effects.

Finally, the current study only examines data from U.S. crewmembers. Supplementeding the data with HNP reports from other Space Agencies could allow more insight into these effects.

**Results**

**Survival Model.** Figure 5 shows the probability of an HNP occurring as a function of years after astronaut selection a) without any distributional assumptions (solid line), and b) with our survival model (red dots). The overall trends agree well. Deviations of the dots from the solid line reflect how our model accounts for variation in HNP risk due to differing numbers and spacing of missions for the 330 astronauts.

Figure 6 shows how the probability of an HNP within one year of a mission landing was estimated to increase with the number of missions. However, because of the lower numbers of astronauts with many missions, the accuracy of this estimated probability becomes worse (increased error bounds) as the number of missions increases.

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**Discussion**

Analysis of the data revealed clear evidence that spaceflight is associated with increased risk of HNP; thus supporting the conjecture suggested by a higher incidence of HNPs shortly after missions. In arriving at this finding we fit a survival model that took into account differences in type, number, and timing of missions as well as the periods of observation for each astronaut. In addition we allowed for the possibility that a certain proportion of astronauts are not susceptible to HNP and would not develop one no matter how long they were observed. The model-based conditional probabilities that each of the 44 HNPs that occurred after at least one mission were attributable to spaceflight, ranged from 0.97 (shortly after a mission) or about 0.2 or lower (at least 30 years after selection). The average value of these probabilities was 0.44.

Other than a detrimental effect of initial age (i.e., selection), we did not find evidence that HNP risk was affected by demographic factors such as gender, height, weight, or whether an astronaut had experience piloting a high-performance jet aircraft. It did appear that astronauts from the pre-Shuttle era, were at lower risk of eventually developing an HNP (p = 0.012). Finally, we did not find evidence that other mission duration type or of landing vehicle had an effect.

**Future Work**

To better assess the effects of spaceflight on HNP risk, additional crewmember data would be ideal. In addition to the U.S. Astronauts included in this study, additional information may be available from the international partners, which could increase the dataset substantially. Additional countermeasures for crewmembers immediately after landing may also be advised to prevent HNP occurrence at the times of highest risk. Finally, continued surveillance of crewmembers after spaceflight could allow a better understanding of this trend.

These results may also be beneficial to current studies of the intervertebral disc and additional analysis of these data in concert with the data from the current studies may improve our understanding of the mechanism of HNP after spaceflight.

**Limitations**

Because this was an observational study it is difficult to separate out the effects of the many spaceflight and demographic factors on HNP risk or to claim causality. In particular, we had no control over when long-duration or capsule-landing missions occurred, thus creating substantial confounds with HNP reporting and diagnosis practices as well as changing criteria for astronaut selection since the pre-Shuttle era. Also, HNP time of incidence was recorded at the time of diagnosis, not at the time of occurrence.

Because the data span the entire Astronaut Corps, effects from improved spaceflight deconditioning countermeasures may obscure the risk of developing an HNP, particularly related to landing length. A majority of the long-duration missions occurred in the past 20 years, when countermeasures have been implemented. In addition, the relatively low numbers of long-duration flights and female astronauts adversely affects the power of tests for these effects.

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**References**