Background

A previous study [1] reported that the instantaneous risk of developing a Herniated Nucleus Pulposus (HNP) was higher in astronauts than in the normal population. This study aimed to separate the effects of spaceflight from those of just being in the astronaut corps on the distribution of HNPs.

Methods

The study was done using data queried by an epidemiologist from the electronic medical record and provided by the Lifetime Surveillance of Astronaut Health. The data included all 330 U.S. Astronauts beginning at selection and continuing throughout their life from 1959 through February 2014. HNP diagnoses were confirmed by Magnetic Resonance Imaging, Computed Tomography, Myelography, operative findings, or through clinical corroboration by a neurosurgeon. In this analysis, cases of HNP diagnosed at or before the astronaut was selected into the astronaut corps were ignored.

Survival Model: We modeled the distribution of \( T_a \), the time from selection into the astronaut corps until diagnosis of HNP. Explanatory variables fall into two categories:

- Flight-related explanatory variables: number and timing of missions, mission duration(s), type of landing vehicle(s), experience as a pilot of a high-performance jet aircraft. For purposes of this study, "long-duration" missions were those flown on Skylab, MIR, or ISS. Others were considered "short-duration" missions. Landing vehicles were classified into "STS" (Space Shuttle) or "capsule" (all others).
- Demographic explanatory variables: age, gender, weight, height, and BMI.

Hazard Functions. The distributions of \( T_a \) and \( T \), as well as \( \lambda(t) \), the probability that an astronaut is in the \( M \) category are modeled through their hazard functions. A hazard function \( h(t) \) is a measure of instantaneous risk of HNP at time \( t \) given that one has not occurred previously. For example, in figure 1, the probability of a first HNP occurring in the small time window shown is approximately the value of the hazard function times the width of the window, \( \delta \), defined as elapsed time from the date of selection.

In this application, hazard functions are modeled as proportional to Weibull-density functions:

\[ w(y, p; y_0) = \left( \frac{y}{y_0} \right)^{p-1} \exp \left( -\left( \frac{y}{y_0} \right)^p \right) \]

Weibull Density Function

After each spaceflight mission:

\[ h(t) = \lambda(t) \exp \left( \int_0^t \lambda(s) \, ds \right) \]

Hazard Function Components.

Astronaut training and lifestyle:

\[ h(y, p; y_0) \equiv \exp \left( \lambda(t) \exp \left( \int_0^t \lambda(s) \, ds \right) \right) \]

Survival Function for \( T_a \) given \( M \):

\[ P(T_a > t | M) = e^{-e^{-\lambda(t) \exp \left( \int_0^t \lambda(s) \, ds \right)}} \]

Non-susceptibility:

The proportion of astronauts that would never develop HNP:

\[ P(T_a = \infty | M) = e^{-\lambda(t) \exp \left( \int_0^t \lambda(s) \, ds \right)} \]

Probability that an HNP at time \( t \) was caused by Spaceflight:

\[ P(T(t) = \infty | T) = e^{-\lambda(t) \exp \left( \int_0^t \lambda(s) \, ds \right)} \]

References


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.

Discussion

Analysis of the data revealed clear evidence that spaceflight is associated with increased risk of HNP development. Using the same method for other outcomes, the model showed a trend of increasing risk over time, but this was not statistically significant in all cases. The results may also be beneficial to current studies of the intervertebral disc and may provide new insights into the mechanisms of HNP after spaceflight.

Future Work

To better assess the effects of spaceflight on HNP risk, additional crewmember data would be ideal. Additional results from 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.