SOYUZ LANDING RISK CHARACTERIZATION

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INTRODUCTION

United States On-orbit Segment (USOS) astronauts have been returning to Earth from the International Space Station (ISS) aboard the Russian Soyuz vehicle since 2003. The energetics associated with Soyuz landings are comparable to our next generation of US space vehicles (Orion, Crew Dragon, and Starliner). Soyuz also lands crew in a similar state of spaceflight deconditioning that is anticipated using the future vehicles. A number of injuries have now been observed during these Soyuz landings. Currently it is unknown how Soyuz landing accelerations and the numbers and types of associated injuries relate to the new occupant protection requirements levied upon future space vehicles. Understanding this relationship will allow better quantification of the risk of injury for future spacecraft designs.

METHODS

An estimate of the occurrences of injury during Soyuz landings has been determined using data contained in NASA flight medicine databases and supplemented with data collected from crewmembers and flight surgeons. At the time of this abstract, 96 USOS astronauts have returned to Earth in the Soyuz (59 US, 31 International Partner, and 6 spaceflight participants). Of that total, data from 80 individual crew landings has been collected through this study. Injuries are classified as either contusions/abrasions, Class I (minor, no medical follow-up), Class II (moderate, medical follow-up necessary), Class III (severe), and Class IV (life threatening). Current NASA occupant protection standards are primarily based on the Multi-axial Dynamic Response Index (MDRI), which is a simple lumped-parameter spring, mass, damper model tuned to human impact responses in three orthogonal axes.

RESULTS

Using what is known about Soyuz landing dynamics from airborne and drop test data, the MDRI predicts essentially no Class IV or III injuries, < 1% Class II injuries, and < 5% Class I injuries. Approximately one-third of all USOS crewmembers for whom data has been gathered have suffered some sort of injury related to landing in the Soyuz vehicle. Most of these injuries fall into the contusion/abrasion category (21.3 %). Class I injuries have been sustained by 5.0% of all crew, and Class II injuries have been observed in 3.8%. No Class III or IV injuries have been sustained to date. Forty-three injuries have been documented, with some crewmembers sustaining more than one injury in a single landing. The knee was the most likely area of injury (n=9), followed by the back (n=8), and then the arm (n=7).

CONCLUSION

Soyuz landing dynamics are the most comparable analog environment for the anticipated loads associated with Orion and commercial crew vehicle landings. The MDRI under predicts the percentage of Class II injuries experienced during Soyuz landings. The MDRI is better at predicting Class I injury occurrences. However, if contusions/abrasions are included in the minor injury Class I category, then the MDRI also vastly under predicts those injuries as well. Given this data, it will be important to re-evaluate the expected injury rates for future vehicles, and work toward improving the predictive tools for spaceflight use. Spaceflight deconditioning may account for some of the under prediction, and work is ongoing to assess the relationship between landing injuries and impact tolerance changes due to spaceflight deconditioning.