

## Shoulder Injuries in US Astronauts Related to EVA Suit Design

<sup>1</sup>R. A. Scheuring; <sup>2</sup>P. McCulloch; <sup>1</sup>Mary Van Baalen; <sup>3</sup>Charles Minard; <sup>1</sup>Richard Watson; <sup>1</sup>S. Bowen; <sup>1</sup>T. Blatt

<sup>1</sup>NASA-Johnson Space Center, Houston, TX; <sup>2</sup>The Methodist Hospital - Dept of Orthopedics, Houston, TX; <sup>3</sup>Wyle, Houston, TX

**Introduction:** For every one hour spent performing extravehicular activity (EVA) in space, astronauts in the US space program spend approximately six to ten hours training in the EVA spacesuit at NASA-Johnson Space Center's Neutral Buoyancy Lab (NBL). In 1997, NASA introduced the planar hard upper torso (HUT) EVA spacesuit which subsequently replaced the existing pivoted HUT. An extra joint in the pivoted shoulder allows increased mobility but also increased complexity. Over the next decade a number of astronauts developed shoulder problems requiring surgical intervention, many of whom performed EVA training in the NBL. This study investigated whether changing HUT designs led to shoulder injuries requiring surgical repair. **Methods:** US astronaut EVA training data and spacesuit design employed were analyzed from the NBL data. Shoulder surgery data was acquired from the medical record database, and causal mechanisms were obtained from personal interviews. Analysis of the individual HUT designs was performed as it related to normal shoulder biomechanics. **Results:** To date, 23 US astronauts have required 25 shoulder surgeries. Approximately 48% (11/23) directly attributed their injury to training in the planar HUT, whereas none attributed their injury to training in the pivoted HUT. The planar HUT design limits shoulder abduction to 90 degrees compared to approximately 120 degrees in the pivoted HUT. The planar HUT also forces the shoulder into a forward flexed position requiring active retraction and extension to increase abduction beyond 90 degrees. **Discussion:** Multiple factors are associated with mechanisms leading to shoulder injury requiring surgical repair. Limitations to normal shoulder mechanics, suit fit, donning/doffing, body position, pre-existing injury, tool weight and configuration, age, in-suit activity, and HUT design have all been identified as potential sources of injury. **Conclusion:** Crewmembers with pre-existing or current shoulder injuries or certain anthropometric body types should conduct NBL EVA training in the pivoted HUT.

### Learning Objectives:

1. The audience will understand mechanisms of shoulder injury related to EVA suit designs
2. Alterations to normal shoulder biomechanics related to pivoted and planar hard upper torso (HUT) EVA suits will be discussed
3. The participant will understand which EVA HUT design predisposes the user to shoulder injury leading to surgery