

HIGH PERFORMANCE EVA GLOVE COLLABORATION: GLOVE INJURY DATA MINING EFFORT

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BACKGROUND: Human hands play a significant role during Extravehicular Activity (EVA) missions and Neutral Buoyancy Lab (NBL) training events, as they are needed for translating and performing tasks in the weightless environment. Because of this high frequency usage, hand and arm related injuries are known to occur during EVA and EVA training in the NBL. The primary objectives of this investigation were to: 1) document all known EVA glove related injuries and circumstances of these incidents, 2) determine likely risk factors, and 3) recommend interventions where possible that could be implemented in the current and future glove designs. **METHODS:** The investigation focused on the discomforts and injuries of U.S. crewmembers who had worn the pressurized Extravehicular Mobility Unit (EMU) spacesuit and experienced 4000 Series or Phase VI glove related incidents during 1981 to 2010 for either EVA ground training or in-orbit flight. We conducted an observational retrospective case-control investigation using 1) a literature review of known injuries, 2) data mining of crew injury, glove sizing, and hand anthropometry databases, 3) descriptive statistical analyses, and finally 4) statistical risk correlation and predictor analyses to better understand injury prevalence and potential causation. Specific predictor statistical analyses included use of principal component analyses (PCA), multiple logistic regression, and survival analyses (Cox proportional hazards regression). Results of these analyses were computed risk variables in the forms of odds ratios (likelihood of an injury occurring given the magnitude of a risk variable) and hazard ratios (likelihood of time to injury occurrence). Due to the exploratory nature of this investigation, we selected predictor variables significant at $p \leq 0.15$. **RESULTS:** Through 2010, there have been a total of 330 NASA crewmembers, from which 96 crewmembers performed 322 EVAs during 1981-2010, resulting in 50 crewmembers being injured inflight and 44 injured during 11,704 ground EVA training events. Of the 196 glove related injury incidents, 106 related to EVA and 90 to EVA training. Over these 196 incidents, 277 total injuries (126 flight; 151 training) were reported and were then grouped into 23 types of injuries. Of EVA flight injuries, 65% were commonly reported to the hand (in general), metacarpophalangeal (MCP) joint, and finger (not including thumb) with fatigue, abrasion, and paresthesia being the most common injury types (44% of total flight injuries). Training injuries totaled to more than 70% being distributed to the fingernail, MCP joint, and finger crotch with 88% of the specific injuries listed as pain, erythema, and onycholysis. Of these training injuries, when reporting pain or erythema, the most common location was the index finger, but when reporting onycholysis, it was the middle finger. Predictor variables specific to increased risk of onycholysis included: female sex (OR=2.622), older age (OR=1.065), increased duration in hours of the flight or training event (OR=1.570), middle finger length differences in inches between the finger and the EVA glove (OR=7.709), and use of the Phase VI glove (OR=8.535). Differentiation between training and flight and injury reporting during 2002-2004 were significant control variables. For likelihood of time to first onycholysis injury, there was a 24% reduction in rate of reporting for each year increase in age. Also, more experienced crewmembers, based on number of EVA flight or training events completed, were less likely to report an onycholysis injury (3% less for every event). Longer duration events also found reporting rates to occur 2.37 times faster for every hour of length. Crewmembers with larger hand size reported onycholysis 23% faster than those with smaller hand size. Finally, for every 1/10th of an inch increase in difference between the middle finger length and the glove, the rate of reporting increased by 60%. **DISCUSSION:** One key finding was that the Series 4000 glove had a lower injury risk than the Phase VI, which provides a platform for further evaluation. General interventions that reduce hand overexertion and repetitive use exposure through tool development, procedural changes and shorter exposures may be one mitigation path, but due to the way the training event times were reported, we cannot provide a guideline for a specific event duration change. When the finger length was different from the glove length, the risk of injury increased indicating that the use of larger finger take-ups could be contributing to injury and therefore may not be recommended. Prior to this investigation, there was one previous investigation indicating hand anthropometry may be related to onycholysis [1]. We found different hand anthropometry variables indicated by this investigation as compared to the prior, specifically differences in middle finger length compared to glove finger length, which point more towards a sizing issue than a specific anthropometry issue. Additionally, although this investigation has identified sizing as an issue, the force and environmental-related variables of the EVA glove that could also cause injury were not accounted for.

REFERENCES

[1] Opperman, R.A., Waldie, J.M.A., Natapoff, A., Newman, D.J., & Jones, J.A. (2010) *Aviat Space Environ Med* 81, 907-913.