IAC-12-A1.6.8

DEVELOPMENT OF A COMPREHENSIVE ASTRONAUT SPACESUIT INJURY DATABASE

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Extravehicular Activity (EVA) is among the most challenging activities in human spaceflight. Maintaining astronaut health and comfort inside the spacesuit is critical to accomplish the tasks required for the mission. However, the current Extravehicular Mobility Unit (EMU) spacesuit causes many astronauts minor musculoskeletal injuries and discomfort, which could lead to suboptimal EVA performance and could impact mission success. This research effort highlights our effort to create a spacesuit injury and discomfort database to better track injuries and countermeasures. The database is developed as part of our broader investigation of "Spacesuit Trauma Countermeasure System Development". The primary objective of the astronaut-spacesuit injury database is to gain insight into the mechanisms causing spacesuit injuries. The database is compiled from a variety of sources, such as existing databases and publications, oral histories, and astronaut debriefs. Once completely assembled, it will include pre-, in-, and post-flight injury information. Data analysis will identify the incidence of particular injuries, the details of injuries (e.g., location and severity), and trends, both in training and in-flight. Anthropometric measurements will be included and data mining techniques will be used to find correlations between anthropometry, suit components, and injury. In addition, the application of current countermeasures is tracked in order to assess their effectiveness. The result is a single reference of spacesuit injury information. The astronaut spacesuit injury database will allow future researchers, spacesuit designers and engineers, medical personnel, and other stakeholders to gain insight into the problems associated with EVA injury and discomfort, and to contribute new ideas and solutions to the EVA injury problem.

I. INTRODUCTION

Extravehicular Activity (EVA) is one of the most challenging activities astronauts need to accomplish when they are in space. The spacesuit must be optimally fitted and comfortable to permit the astronauts to concentrate on their tasks. However, the current United States (US) spacesuit, the Extravehicular Mobility Unit (EMU), causes minor musculoskeletal injuries and discomfort to many astronauts[1].

Injuries occur both in training and in-flight[1]. A significant portion of EVA training is conducted at the Neutral Buoyancy Laboratory (NBL) at NASA Johnson Space Center, located in Houston, Texas. The NBL facility consists of a 23.8-million-liter water tank to simulate weightlessness for astronaut training. The NBL contains full mock-ups of the International Space Station (ISS) and other space structures[1].

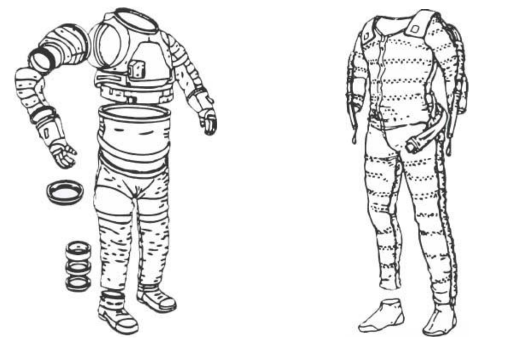
During training, astronauts incur injuries not seen on orbit due to the presence of gravity. Astronauts train in the NBL approximately 10-12 hours for each planned EVA in orbit. The amount of EVA training has increased over the past ten years, due to the demands of ISS operations. Hence, minor (and some major) injury incidences and discomfort episodes during training have become more frequent among the corps of astronauts[1].

Injuries might also occur during orbital EVA. The gas-pressurized spacesuit is stiff and rigid, making it very difficult for the astronauts to move inside the suit[1-2-3]. Astronauts need to align their body joints to the spacesuit joints in order to bend their limbs, and this requires detailed suit sizing and fit. EVA tasks often require the astronauts to work at the boundary of their work envelope, causing them to exert significant force against the spacesuit to perform difficult movements. In addition, astronauts use the lower body to produce counter-torques against footholds to stabilize themselves. Hence, an improper boot fit and fatigue might consequently lead to legs and feet injuries[1-2].

The Extravehicular Mobility Unit (EMU) spacesuit

The current spacesuit, or EMU, and the comfort garments are shown in Figure 1. The EMU is a 29.6 KPa (4.3 psi), 100% oxygen spacesuit made of 14 different layers[2]. The gas pressurized spacesuit requires astronauts to use their strength to move the suit, which can be fatiguing. This, combined with the demanding tasks astronauts need to accomplish in space, can lead to musculoskeletal injuries that could affect astronauts' performance throughout the space mission[4].

The main components of the EMU are the liquid cooling and ventilation garment (LCVG), the spacesuit assembly (SSA), and the life support system (LSS). The LCVG is the primary protective component. It covers the body from the wrists to the ankles and neck, and its function is to maintain astronaut body temperature by water circulation in plastic tubes woven through the garment. The spacesuit assembly includes several components. The hard upper torso (HUT) is a fiberglass shell to which arms, helmet and low body are attached, seen in Figure 2. An in-suit drink bag containing up to 0.95 L of drinking water is attached to the right inner front part of the HUT. The arm assemblies are two flexible anthropometric pressure vessels that cover the arms. The glove assemblies attach to the arm assemblies. They are designed to provide the best possible dexterity, tactility and precision, and they are considered the most challenging part of the spacesuit to design, and are currently one of the major sources of injury and discomfort. The lower torso assembly is a flexible anthropometric pressure vessel that covers the waist, lower torso, legs and feet. The boots, which are available in two sizes, can be modified with boot-sizing inserts to accommodate different users. Finally, the communication carrier assembly is a cap that contains earphones and a microphone, and it is always placed beneath the helmet[2-4].



A) EMU spacesuit B) Comfort garment

Fig. 1: EMU spacesuit pieces and comfort garment. A) Exploded view of the EMU (Hamilton Sundstrand). B) Each of the comfort pieces, including the LCVG with padding, ventilation tubes, and boot inserts ("Human Spaceflight")

The life support system includes a backpack containing the oxygen, water, and electric and communication components. It also removes carbon dioxide and humidity from inside the spacesuit. The display control module, or DCM, provides useful information about the suit properties. Finally, an additional spacesuit propulsion component is the simplified aid for EVA rescue, or SAFER system, for emergency situations for untethered astronauts in order to return safely to the spacecraft. Furthermore, there are additional support equipment, such as the electrical harness, other comfort garments, and a variety of tools[2-4].

There are minor differences between the EMU used in flight versus in training. The spacesuit used in the NBL is certified only for training and it is categorized as Class III[1]. Unlike the EMU used in space, the training spacesuits are tethered to an umbilical, which delivers breathing gas, cooling water and communications[2]. Currently, two different versions of the HUT are used in training: the pivoted HUT and the planar HUT. The older version, or the pivoted HUT, has a bellows at the scye (shoulder) bearing, giving it more mobility over the planar HUT, whose rotating bearing attaches directly to the upper arm piece. The pivoted HUT is no longer used on orbit since a rupture in the bellows would be a catastrophic failure of suit integrity[4-5]. It is believed that many shoulder musculoskeletal injuries are related to the introduction of the planar HUT[2].

II. EVA INJURIES

Astronauts need to be physically fit in order to conduct operations in space[6]. Due to the risky nature of their duties, astronauts are subject to physical training that might lead to musculoskeletal injuries. This is particularly true for astronauts who are going to perform extravehicular activity (EVA). Furthermore, the deconditioning that astronauts suffer in space, such as muscle loss, might increase the risk of this form of injuries during or after a long spaceflight period[7].

To some extent, astronauts have always experienced injuries during EVA. In general, these complaints have been minor and anecdotal. However, during the last few decades, there have been an increased number of reported injuries, causing concern in the human spaceflight community. Therefore, researchers and flight surgeons are attempting to understand the nature of EVA injuries[5].

Hand injuries are the most common injuries both in training and in-flight[4-7]. They are due in part to the axial force applied to fingers in order to move the pressurized and stiff gloves[3-8-9]. Injuries also occur due to the finger pad pressure needed to articulate the gloves[10]. The presence of moisture in the gloves also exacerbates the onset of hand injuries[3-8-9]. Astronauts may develop fingernail delamination, or onycholysis, after an EVA[7-8]. Hand injury countermeasures include optimizing glove fit, keeping finger nails short, and using dressings and topical applications[4-8]. Furthermore, the necessity to improve the dexterity of the glove as a top priority has been recommended by former Apollo astronauts[11].

Shoulder injuries not only have a high incidence rate during training, but are also some of the most severe. In general, shoulder injuries are minor and self-limited, but in several occasions have required surgical intervention[5]. The shoulder injury Tiger Team was created in December 2002 to understand the relationship between shoulder injuries and EVA training at the NBL. The study found that some of the primary factors causing shoulder injuries during training were the restriction of the shoulder mobility associated with the use of the Planar HUT, suboptimal suit fit, the inverted positions of the astronauts during training, the use of heavy tools, performance of overhead tasks, and the high frequency of NBL runs[5]. Several countermeasures have been developed to avoid shoulder injuries during EVA. The EMU shoulder harness, which is shown in Figure 2, is installed inside the HUT for NBL training to distribute the shoulder loading by mean of Teflon trips, dispersing the pressure points. In addition, several combinations of comfort pads are used to prevent hard contact between the astronaut shoulder and the hard parts of the spacesuit[5]. These countermeasures have proven to be fairly ineffective and have low compliance usage.

Feet were also identified as an area where injuries and pressure contact points caused by the EMU occur frequently. Foot injury countermeasures include the use of BSI's (Boot Sizing Inserts) and the use of protective dressings[4].

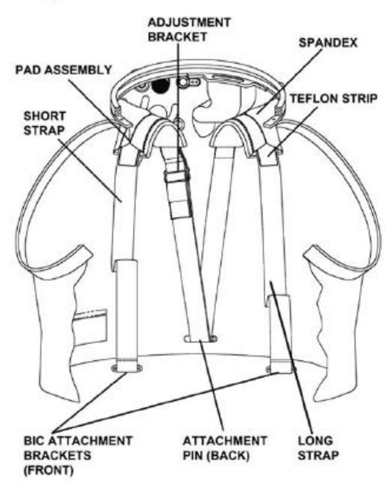


Fig. 2: View of the shoulder harness inside the HUT[5] (EMU Shoulder Injury Tiger Team Report, p.52, Williams D. & Johnson B., 2003)

Additional injuries are seen over elbow, wrist, knee, or trunk regions, generally due to hard contact with the spacesuit causing pressure points, abrasions and lacerations. Countermeasures include the use of comfort pads and protective dressings[4-7].

Despite the countermeasures described above, astronauts are continuously at risk of EVA injury. Figure 3 shows a conceptual representation of the injury hotspots caused by the EMU. Thus, other recommendations for new countermeasures have been proposed, such as improving suit fit adjustments, medical screenings before training, personalized training programs, and redesign of spacesuit components contributing to injuries[4].

III. SOURCES OF INFORMATION

The primary objective of the database is to gain insight into the mechanism of spacesuit injuries. Currently, EVA injury information is spread among different sources. Thus, researchers, spacesuit designers or other stakeholders who want to specifically search for EVA injury information need to go through a disconnected search process. Our research, in collaboration with researchers at NASA's Johnson Space Center, consists of collecting this data from all sources and consolidating them together to produce an efficient spacesuit injury database.

Literature review

We performed an extensive literature review concerning astronaut musculoskeletal injuries in order to identify suitable sources of information for the consolidation of the database.

Fig. 3: EMU injury hotspots. Conceptual representation of the areas where injuries and pressure contact points most often occur.

Several studies have quantified and tracked astronaut injury. However, EVA specific information is limited. In 1996, Jennings and Bagian conducted a musculoskeletal injury review of the U.S. Space Program[6]. They collected the orthopedic injury history of U.S. astronauts from January 1987 to March 1995. They found 26 events that resulted in fractures, the ribs being the most common location with 5 occurrences. Regarding soft tissue and ligament injuries, knee injuries were the most common and serious, with 19 occurrences requiring surgery. In addition, they found three Achilles tendon ruptures, and six ankle ligaments injuries (only one required surgery). Four shoulder injuries were also identified: two acromioclavicular separations, one rotator cuff injury, and one chronic acromioclavicular problem secondary for competitive swimming. Two of them required surgery. However, there is no explicit information about the origin of three other shoulder injuries, or if they are related to EVA activities[6].

Another study in 1999 examined the musculoskeletal injury rates (pre-flight and post-flight) of Shuttle astronauts between STS-1 (1981) and STS-89 (1998)[12]. Results showed that the musculoskeletal injury rate of Shuttle astronauts is significantly higher than the injury rate of the control group consisting of non-astronauts. Additionally, the injury rate of astronauts during their mission period was three times higher than the overall astronaut injury rate. The mission period is defined as the one-year pre-flight and one-year post-flight period. In contrast, their injury rate outside the mission period was about half the overall rate. As expected, this result confirms that both the higher physical activity during the pre-flight period and the deconditioned state of astronauts after microgravity during the post-flight period resulted in more injuries[12].

In another study specific to EVA injury, Strauss et al. collected 770 questionnaires about astronaut injuries during EVA training in the NBL[4]. The questionnaires were collected from 86 astronauts after astronaut training sessions over 18 months (from July 19, 2002 to January 16, 2004). A total of 352 symptoms were reported, and the highest number of injuries occurred in the hands (47.2%), in the shoulders (20.7%), and in the feet (11.4%)[4].

The first study to examine astronaut's in-flight injuries was conducted by Scheuring et al. in 2009[7]. Scheuring and his team analyzed all injuries, including EVA, by anatomical location, type, and mission activity. A total of 219 in-flight musculoskeletal injuries were found, and hand injuries were identified as the most common ones (more than 70), followed by back (30), and shoulders (more than 20). Abrasions and lacerations represent the most common type of injury. The mission activity with the highest number of injuries is the "crew activity" (more than 80), followed by "EVA activity" (50) and "exercise" (31)[7].

Although these studies address astronaut injuries, some of them do not focus on EVA injuries specifically. Others include EVA activities but the information is embedded in a broader category. Thus, more research is necessary to extract the EVA specific information.

<u>Other sources</u>

In addition to the information published in the literature described above, three additional sources of information have been identified and are presented in Table 1. The three data sources are useful for our research effort, but none of them completely satisfies our requirements. The Injury Tracking System (ITS) is an astronaut database that contains pre-, in-, and post-flight information. It is one of the most complete existing sources of injury data. However, it also includes injury data not related to the spacesuit[8-13]. The Lifetime Surveillance of Astronaut Health (LSAH) program was created to assess the long-term health of the astronauts during spaceflight and training. The LSAH tracks medical records, and uses JSC employees as a control group[14]. However, spacesuit-specific injuries are in general, short-term, whereas the LSAH is focused more on long-term concerns. Third, the Astronaut Strength and Conditioning and Rehabilitation (ASCR) program was designed to help astronauts meet the physical demands of spaceflight and upon their return to Earth's gravity. Personal records, data from rehabilitation programs, and records of the personnel involved in the programs constitute useful sources of injury information.

IV. DESCRIPTION OF THE DATABASE

Unlike other existing databases, we are developing an astronaut spacesuit injury database focused specifically on EVA. Data related exclusively to EVA injuries was obtained from a variety of sources, such as existing databases and publications, oral histories, and astronaut debriefs. To enhance existing studies, our database will include pre-, in-, and post-flight injury information. Once assembled, the database will be useful in tracking countermeasures and assessing their effectiveness.

The creation of the astronaut spacesuit injury database consists of two separate phases. The first phase aims to gather previously published, public information, creating a first compendium of EVA injuries. The second phase consists of the enrichment of the database with information accessible from JSC medical records and the three resources described above. This allows us not only to increase the number of entries in the database by incorporating unpublished information, but also to provide more details about each injury, such us anatomical locations, causes, countermeasures, NASA missions, and treatments. In addition, anthropometric measurements are also included and data mining techniques will be used to find correlations between anthropometry, suit components, and injury.

In the first step of this process, we performed a comprehensive review of past astronaut injuries studies. For each study, we extracted the data related to EVA and used it to consolidate the initial EVA injury database.

Sources	Description	Data source	Additional information
Injury Tracking System (ITS)	Contains pre-, in- and post-flight information	NBL records; Electronic medical records	Allows remote access with authorization. Not all injuries spacesuit related
Lifetime Surveillance Astronaut Health (LSAH)	Long term health issues	Astronaut medical records over career. JSC employees as control	Spacesuit injuries are short term, minimal published data for EVA
Astronaut Strength, Conditioning, and Rehabilitation (ASCR)	Preparation and recovery from physical demands of spaceflight	Training and rehabilitation personal records	Personnel as additional source of information

Table 1: Existing sources of astronaut injury information

Although literature concerning astronaut injuries is fairly large, many of the articles do not specifically address EVA injuries. Hence, only three useful references were found for our research effort.

The first reference is the study by Scheuring et al. on astronaut in-flight injuries throughout the U.S. space program[7]. Due to its particular characteristics, EVA activity is recognized as one of the leading causes of in-flight injuries. Scheuring et al. identified 50 musculoskeletal injuries related to the EVA suit. The study provides information about the anatomical location of the EVA suit injuries, being the most common the hand (20), the foot (11) and shoulders (6). Figure 4 shows the distribution of in-flight injuries due to EVA suit[7].

Nine of the 50 EVA suit injuries are associated with the Apollo program and the EVAs astronauts performed on the surface on the Moon. Five of them were located at the hands and were due mainly to a poor-fitting glove and/or lack of inner liner or comfort glove. Two other injuries were located at the wrist (laceration due to the suit wrist ring cutting into the skin, and extensor wrist pain and soreness where the suit ring and sleeve repetitively rubbed over the joint), one at the shoulder (significant strain during surface core drilling experiment), and one at the leg (significant muscle fatigue occurred in the lower extremities due to the long distances covered on the lunar surface)[7].

In addition, five other noteworthy EVA injuries not due to the interaction with the spacesuit were identified. Four of them were defined as muscular strains while performing EVA, and the fifth was a hand abrasion immediately after the EVA[7].

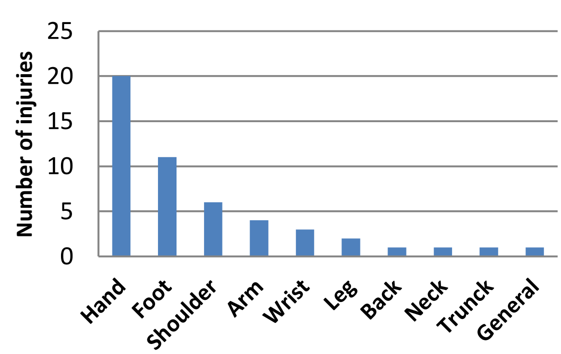


Fig. 4: Location of in-flight musculoskeletal injuries due to EVA suit[7] (Musculoskeletal injuries and minor trauma in space, p.121, Scheuring R., 2009)

The study also provides data on injury types (abrasion, contusion, strain, laceration, sprain and dislocation), crew activity (such as three injuries during donning suit), and other NASA space programs (Gemini, Mercury, Skylab, Shuttle, NASA/MIR, STS). However, this information is not given explicitly for the particular case of EVA injuries.

The second reference used for the creation of our database is the study that Strauss et al. performed on astronaut injuries during EVA training at NASA's Neutral Buoyancy Laboratory in Houston, TX[4]. As already mentioned, 352 suit symptoms comments were collected in 770 questionnaires distributed to 86 astronauts, from July 19, 2002 to January 16, 2004. Figure 5 shows the 352 injuries classified by anatomical location. Again, the highest number of injuries occurred in the hands (166), in the shoulders (73) and in the feet (40)[4].

In addition, the study performed by Strauss also provides information about the average severity of the injuries in a scale of 0-5, and the causes of the injuries, both of them based on the anatomical location. Fingertips/nail contact with the glove is the most frequent cause of hand injuries. Contact with the HUT and impingement injuries constitute more than 90% of shoulder injuries[4]. A summary of causes of astronaut EVA injuries is presented in table 2.

Finally, the third reference is the "EMU Shoulder Injury Tiger Team Report", completed by David R. Williams and Brian J. Johnson in September 2003[5]. The objective of the study was to identify the potential risks of EVA shoulder injuries during training, and to make recommendations to prevent those injuries. A survey distributed to 42 astronauts and astronaut candidates was conducted between Fall 2002 and January 2003. Among all the participants, 22 astronauts, 19 males and 3 females, had already participated in EVA training. Results showed that 14 out of the 22 astronauts have experienced some degree of shoulder pain during training, two cases required surgical treatment.

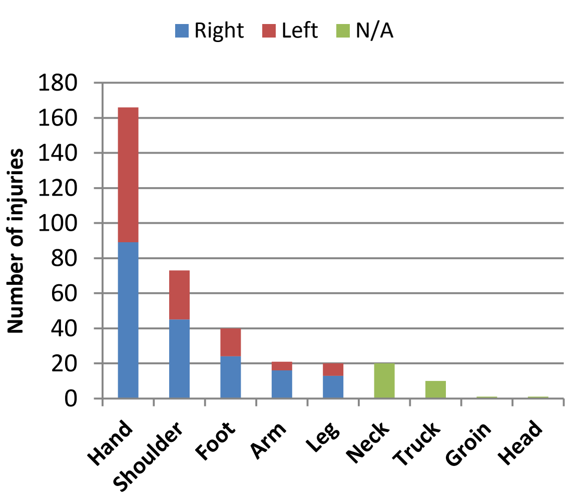


Fig. 5: Location of training musculoskeletal injuries due to EVA suit[4] (Extravehicular Mobility Unit Training and Astronaut Injuries, p.471, Strauss S., 2005)

The study provides other useful information about the participants, such us demographic data, conditioning data (frequency of exercise, type of workouts, flexibility data), previous injuries data, shoulder and neck pain data during training, and shoulder injury data. Furthermore, the study identified possible causal mechanisms of shoulder injuries, two of the most common were the inverted position during training and the use of the planar HUT[5]. Table 3 shows the list of possible causal mechanisms of shoulder injuries.

Anatomical Location	Right/ Left	Average severity 0-5	Cause
Hands	89 Right 77 Left	1.13/5	Fingertips/nail contact – 55% Other glove contact – 35% Fatigue – 8%
Shoulders	45 Right 28 Left	1.86/5	HUT contact – 47% Strain, sprain, tear, overuse, and impingement injuries – 46% Harness contact – 7%
Feet	24 Right 16 Left	1.66/5	Boot contact causing dorsal foot pain – 60% Hard contact with the front of the boot causing toe pain – 28% Poor protection and lack of support causing heal and arch pain – 12%
Arms	16 Right 5Left	1.65/5	Contact causing abrasions and contusions – 65% Strains – 35%
Legs	13 Right 7 Left	1.56/5	Knee contact – 95% Ankle contact – 5%
Neck	N/A	0.8/5	Contact with Teflon inserts – 95% Strains – 5%
Truck	N/A	0.4/5	Back contact – 54% Chest contact – 46%
Groin	N/A	4/5	Soft good contact
Head	N/A	2/5	Contact with the bridge from eyeglasses

Table 2: Average severity and causes of astronaut EVA injuries by anatomical location discussed in Strauss study [1-4]

Possible Causal Mechanisms	%
Training in inverted position	25.8%
Use of Planar HUT	22.6%
Repetitive motion	19.4%
Use of heavy tools	16.1%
Frequent NBL runs	6.5%
Specific arm position	6.5%
EMU donning	3.2%

Table 3: Possible causal mechanisms of shoulder injuries during training[5] (EMU Shoulder Injury Tiger Team Report, p.22, Williams and Johnson, 2003)

Another important aspect of the astronaut spacesuit injury database concerns the countermeasures used to prevent EVA injuries, and the assessment of their effectiveness. During the first phase of the database development, a list of all current countermeasures has been assembled and associated with the causes and injury locations. Some of the most common countermeasures are the use of dressing and topical applications, the use of comfort pads, and optimal glove and suit fitting[4-5-7]. Table 4 shows a list of current countermeasures, classified by anatomical location and associated with the causes.

The first phase of the development of the astronaut spacesuit injury database has been completed with the compilation of all data related to EVA injuries, based on the publications cited in this paper. The second phase of database development will take place when access to the JSC medical records, which has been requested, has been approved.

V. SPACESUIT TRAUMA COUNTERMEASURE SYSTEM

The database is developed as part of our broader project called “Spacesuit Trauma Countermeasure System Development”. The aim of this broader project is to improve future spacesuit design by contributing to injury analysis in different areas, the first of which is the above mentioned database development and the use of data mining techniques to find trends between anthropometric measurements, spacesuit components and injury.

Anatomical Location	Cause	Countermeasures
Hands	Axial loading and moisture in the gloves yielding to fingernails delamination (onycholysis)	Provide optimal glove fit, keep nail short, use of appropriate dressings/topical application, including Dermabond, Tegaderm, Band-Aids, Moleskin, and tape that protects fingertips/nails and help to keep them dry
Hands	Contact and compression injuries	Provide optimal glove fit, arm length, and elbow alignment, have protective dressing availability, and make available primary or acceptable backup gloves
Shoulders	HUT contact	Use of shoulder pads: 338, 335, 336 and 337, and use of Teflon inserts
Shoulders	Harness contact	Optimal fit, unique fit adjustments for the pivoted and planar HUT
Shoulders	Strain, sprain, tear, overuse, and impingement injuries	Training and test planning for the use of heavy tools, on the appropriate use of diver assistance, on working inside the EMU work envelope, and on avoid known shoulder-stressing manoeuvres
Feet	Boot contact, lack of protection, and lack of support	Avoid folds in soft goods, including socks, LCVGs, and EMU bladder folds, optimize boot fit with BSIs, wear heal pads/thermal slippers, and effectively use of protective dressings such as Moleskin
Legs	Knee and ankle contact	Use of LCVG knee comfort pads 333, and use of protective dressings as Moleskin
Arms	Hard contact causing abrasion and contusion (generally at the elbow)	Use of comfort pad 334.Use of protective dressings such as Mosite or Moleskin
Neck	Strains due to uncomfortable head and neck position	Improve the shaping and fitting of shoulder pads with Teflon inserts. Consider the different head/neck height in the helmet in various configurations in the pool
Trunk	Back and chest contact	Use of shoulder stabilization back pad 339. Use of protective dressings as Moleskin. Ensure HUT sizing
Groin	Soft good suit contact	Use of crotch pad for sizing and protection

Table 4: List of current countermeasures to avoid EVA injuries, classified by anatomical location and associated with the causes[1-4]

A second goal of our EVA injury prevention and countermeasure research effort is to develop a wearable body pressure sensing garment to better understand how astronauts move inside the spacesuit. Pressure sensors integrated into the garment will detect the areas of the body in contact with the spacesuit and will quantify the magnitude of the contact pressure.

The third research goal is to develop a human-spacesuit interaction model that will reproduce the motion of the human inside the spacesuit to simulate the mechanisms of spacesuit injuries. The model will be developed in OpenSim[15], an open source platform capable of performing inverse kinematics, inverse dynamics and more complex musculoskeletal analysis[16]. We will use motion capture data to understand the human biomechanics inside the spacesuit. In addition, we will quantify changes between suited and unsuited conditions.

The ultimate objective of this project is to prevent injury during EVA. Hence, the final goal is to design new prototype protection devices that will address the underlying causes of astronaut injuries elucidated by the database, pressure sensing garment, and modeling work. The new protection devices will be tested and eventually integrated into the inner spacesuit layer, similar to the LCVG, to improve safety and comfort inside the spacesuit.

VI. EDUCATION AND OUTREACH

A final aspect of our EVA injury research prevention project is to solicit wide-ranging creative ideas to inform our research as well as to consider and analyze all proposed injury solutions from the public.

We are in contact with NASA Education Office at JSC to dovetail our efforts to facilitate public engagement in our project. Education materials such as online modules, a high-school design competition or a virtual classroom, seem to be the most promising avenues for public engagement. Furthermore, an EVA outreach video is also being produced.

VII. CONCLUSION

Our objective is to consolidate a comprehensive EVA injury database. It will be a valuable tool for engineers, researchers and other stakeholders related to current and futures spacesuits. In addition, the database itself and the data mining results will establish the basis and approach for other related, aspects of the project.

The creation of the database is ongoing. The first phase has been accomplished, consisting of gathering published, public information. An extensive literature review has been conducted, collecting the three main published references concerning EVA injuries. The second phase relies on accessing JSC medical records, and appropriate data requests are completed and approval is pending.

Our effort is important to help maintain the safety and security of astronauts while they perform EVA. Enabling injury-free EVA will allow us to perform a higher number of safe, efficient sorties, which are necessary for the success of future human spaceflight missions.

Acknowledgements

This project is funded through the NASA Grant NNX12AC09G “Spacesuit Trauma Countermeasure System for Intravehicular and Extravehicular activities”. Additional support is provided by the Fulbright Commission and the National Science Foundation Graduate Research Fellowship Program. The authors would like to thank their collaborators at NASA Johnson Space Center: David Baumann, Lindsay Aitchison, Dr. Sudhakar Rajulu, Amy Ross, and Dr. Richard Scheuring.

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