

# **DEVELOPMENT AND EVALUATION OF IMPROVED PATIENT TRANSPORT SYSTEM**

J Ryan Stanfield, University of Utah  
Siddharth Gharpure, University of Utah

[Ryan.Stanfield@utah.edu](mailto:Ryan.Stanfield@utah.edu)

## **ABSTRACT**

Lifting and carrying activities account for the majority of injuries, worker compensation cost, and subsequent days away from duty in the Emergency Medical Services (EMS) field. The research in this paper discusses the safety and ergonomic effects on technicians (primarily firefighters and paramedics) of the EMS industry. The study compared the conventional form of patient transport with a newly developed form of patient transport implementing an aftermarket product known as the Descent Control System (DCS). Data for the biodynamic analyses was provided by Paramed Systems, Inc., which was initially collected during a study at the Ohio State University on the benefits of the Descent Control System. Data for the safety analyses on failure modes and consequent effects was carried out by Paramed Systems, Inc., and the University of Utah. Results of the study indicate that proper implementation of the Descent Control System during patient transport has beneficial impact on the operator's muscle activity, and reduces potential injuries to the operators and patients.

## **INTRODUCTION**

According to the United States Bureau of Labor Statistics, incidence rates for injury and illness for firefighters and EMS workers is roughly four and six times that of the national average, respectively (BLS, 2003). In 2002 the United States EMS industry reported a total of 7,033,996 patient transport calls in 24 States and Territories and estimates the number to be near 19 million nationwide, which exposes personnel to musculoskeletal damage, predominantly occurring in the lower back. Lower back damage is principally due to overexertion while carrying, bending, and twisting during patient transport. In 2003 the National Fire Protection Association (NFPA) stated that 51% of reported injuries were strain, sprains, and other muscular pain. For the number of strains and sprains in non-fire emergencies, such as EMS calls, the percentage climbs to 58%, according to the NFPA. It is interesting to note that 61% of calls were medical, instead of fire related. The BLS published the same figure of 58% for the number of strains and sprains reported in the ambulatory healthcare services industry in 2003.

Research conducted by the Ohio State University reveals that the cost of worker compensation for those in Fire and EMS related job fields is double that of the national per-claim average in the U.S. Musculoskeletal injuries account for about one-half of the cost and one-third of the number of claims for all of worker's compensation granted. It is widely accepted that about 60% of

adults in the United States are overweight, and 20% are obese. Lifting and carrying patients that are overweight and obese is continually increases, putting technicians at a much higher risk for injury, as well as greater demand for physical input in general.

## METHODS

The research and development of improved patient-transport devices is paramount for the firefighter and EMS industries to reduce the number of injuries that occur in the field caused by and during lifting and transporting those in need. The injury statistics for these fields of ambulatory health services have prompted a few parties in the medical device industry to respond by designing and manufacturing transportation devices more conducive to ergonomic and safety issues for both the patient and the technician. One of the devices in the industry that has been created to help remedy these alarming facts is the Descent Control System. The Descent Control System is a device that has been designed to retrofit to any existing patient transport stretcher in the pre-hospital market in order to aid in the transport of patients down stairs or other steep declines. The DCS design is simple in nature, as seen in Figure 1; consisting of a track system that slightly elevates the existing stretcher casters off of the ground to provide a long, smooth surface that stays in contact with the toe of the stairs or uneven ground during transport, the Descent Control System is designed to reduce back injury risks to firefighters and paramedics. Thus, it is a further objective to reduce the cost of worker compensation claims, as well as the industry cost of days away from work due to such injuries, by altering the patient transport duty to one that involves stable pushing and pulling actions rather than one that requires lifting and carrying.



Figure 1. The Descent Control System

Much study and research has gone in to the effectiveness and applicability of the Descent Control System in the EMS field both before and since its initial launch to the retail market. The information presented here reflects those studies carried out on the DCS relating to an ergonomic and safety perspective. Specifically, the stated research has been directed more toward the applicability of safety and ergonomics to the operator, but also has relevance to the safety of the patient being transported.

## ANALYSIS

One of the earliest third-party research studies on the DCS was performed and carried out at the Ohio State University under the direction of Dr. Steven Lavender. The research consisted of electromyographic (EMG) data collection and analysis by recording and processing signals from 8 trunk muscles of 22 individual paramedics and firefighters. The paramedic/firefighters were grouped into 11 two-person teams, each consisting of a “leader” and a “follower.” The leader was the individual who was at the foot-end of the stretcher and descended the stairs backwards, while the follower was at the head-end of the stretcher and descended the stairs forwards. The muscles from which the EMG data was collected included the right and left Erector Spinae (back), Latissimus Dorsi (back), Rectus Abdominus (stomach), and External Oblique (anterior). Data samples were gathered during the stair initiation, as well as the stair descent (Lavender, 2004).

Failure mode and effect analyses (FMEA) have also been carried out identifying hazard categories and mishap probabilities for both operators and patients. The included analyses are specific to possible failure modes during patient transport down stairs consisting specifically of a two-person team of paramedic/firefighters moving a stretcher with a securely-loaded patient both with and without the implementation of the DCS. The examined modes include device component failure, operator failure, and surrounding environment effects.

## RESULTS

Data from the electromyographic analysis was normalized to the peak signal acquired by the maximal exertions of each muscle region, and this data was analyzed using two methods. The first method analyzed the mean EMG signal acquired while the paramedic/firefighters began or maintained stair descent, while the second method analyzed the 90<sup>th</sup> percentile figures attained for the data collection. Figures 2 and 3 below show the mean values analyzed for the leader and follower, respectively. Muscle groups mentioned above are abbreviated as acronyms denoting right and left. Muscles exhibiting a substantial statistical change are denoted by an “\*”.

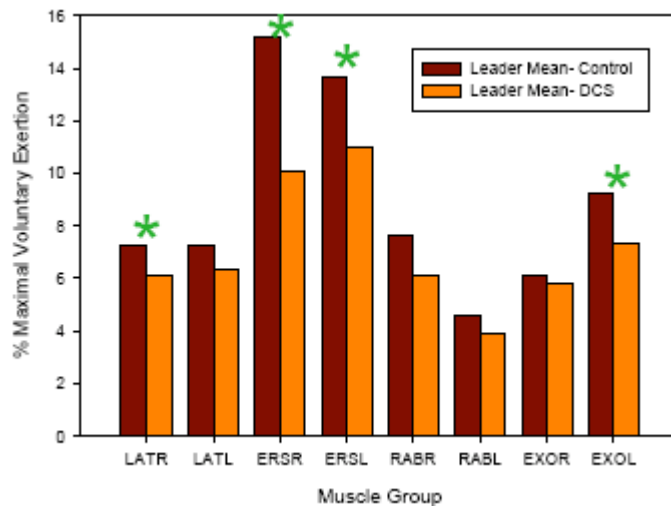


Figure 2. Conventional vs. DCS Stretcher Analysis of Mean values for the Leader

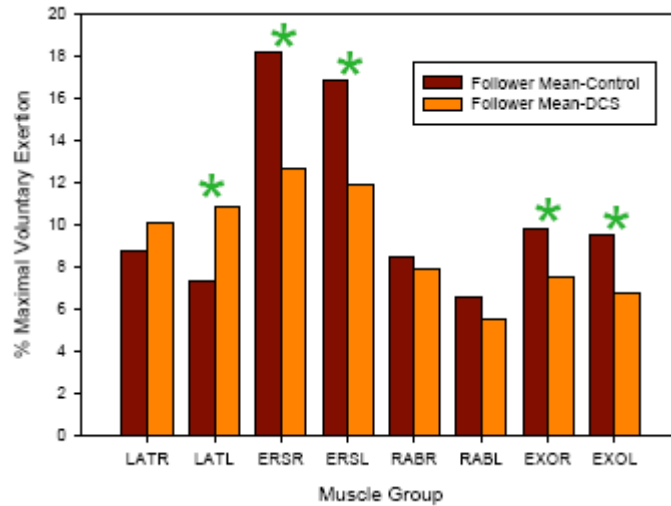


Figure 3. Conventional vs. DCS Stretcher Analysis of Mean values for the Follower

The following tables (1 and 2) show the hazard category and mishap probability descriptions for the FMEA, respectively. Table 3, on the following page, gives an organized summarization of two FMEA for the transporting team, device, and patient system. One of these analyses examines a patient transport while descending stairs with proper implementation of the DCS, and the other analysis examines the same situation while implementing the conventional carrying method of a stretcher. The two FMEA analyses were combined into one table because the only variable column in both the analyses was the hazard category. Comments for FMEA of the cot equipped with the DCS are marked with a “<sup>1</sup>”, and comments for FMEA of the cot not equipped with the DCS are marked with a “<sup>2</sup>”. The data and interpretation of this FMEA was generated principally through acute observation of patient transport performed by paramedic/firefighter teams at various locations in real-world applications and environments.

Table 1. Hazard category description

| Hazard category | Description  |
|-----------------|--|
| Critical        | May cause sever injury, resulting in long term damage                |
| Significant     | May cause minor injury, resulting in lost workdays                   |
| Minimal         | Not cause injury, but cause some stress and strain                   |
| Negligible      | Not affect safety of health, but is a violation of specific criteria |

Table 2. Mishap Probability description

| Mishap Probability | Description  |
|--------------------|--|
| Frequent           | Likely to occur frequently                         |
| Probable           | Will occur several times in the life of a facility |
| Occasional         | Likely to occur in the life of the facility        |
| Remote             | Unlikely, but could happen                         |

Table 1. Patient transport FMEA for implementation of DCS

|                       |  | FAILURE MODE AND EFFECTS ANALYSIS  |  |                          | Page   |
|-----------------------|--|--|--|--------------------------|--|
| Project:              | Patient transport down stairs  | Date   | April 2005   | Analyst                  | Siddharth Gharpure, Ryan Stanfield   |
| System:               | With and without (conventional method) the DCS   | Hazard category with DCS   | Hazard category without DCS  | Failure frequency        | Remarks  |
| Component description | Effect on the system   |  |  |                          |  |
| Cot                   | Injuries to follower<br>Injuries to leader<br>Injuries to patient  | Significant<br>Significant<br>Critical                                     | Significant<br>Significant<br>Critical   | Remote                   | <sup>1,2</sup> May cause a Significant injury depending on how well the operators handle the situation post device failure   |
| DCS                   | Injuries to follower<br>Injuries to leader<br>Injuries to patient  | Significant<br>Significant<br>Minimal                                      | NA<br>NA<br>NA   | Remote                   | <sup>1</sup> The cot is carried manually by the operators. Injuries to operator and patient are similar to that caused when the cot is not equipped with DCS. The weight of the DCS is negligible when compared to combined weight of patient and cot  |
| Follower              | Injuries to leader<br>Injuries to the patient<br>Damage to the device<br>Injuries to leader<br>Injuries to the patient<br>Damage to the device     | Minimal<br>Negligible<br>Negligible<br>Minimal<br>Negligible<br>Negligible | Significant<br>Critical<br>Minimal<br>Significant<br>Critical<br>Minimal       | Occasional<br>Occasional | <sup>1</sup> Follower helps to guide the cot and control its speed. If control is lost the leader may be able to control the situation   |
| Leader                | Injuries to follower<br>Injuries to the patient<br>Damage to the device<br>Injuries to follower<br>Injuries to the patient<br>Damage to the device | Minimal<br>Negligible<br>Negligible<br>Minimal<br>Negligible<br>Negligible | Significant<br>Critical<br>Minimal<br>Significant<br>Critical<br>Minimal       | Probable<br>Occasional   | <sup>1,2</sup> Leader does most of the work and has to descend backwards, so the probability of losing control is higher.<br><sup>2</sup> May cause a Critical injury as the cot can over-run the leader.  |
| Patient               | Stress to the operators  | Minimal  | Minimal  | Occasional               |  |
| Steps                 | Injuries to follower<br>Injuries to leader<br>Injuries to the patient<br>Injuries to follower<br>Injuries to leader<br>Injuries to the patient     | Negligible<br>Negligible<br>Negligible<br>Minimal<br>Minimal<br>Negligible | Significant<br>Significant<br>Minimal<br>Significant<br>Significant<br>Minimal | Frequent<br>Probable     | <sup>1</sup> The effect of angle of descent can be neglected as the force required to control the cot does not change drastically. Also, braking system can be used to control the speed.<br><sup>1</sup> On damaged steps the operator has to manually pick up the cot on the side of the damaged step which can cause some stress to the operator. It is still easier then carrying the cot not equipped with the DCS system |

## **DISCUSSION**

The EMG data for the mean and 90<sup>th</sup> percentile figures were extremely similar in the variation of muscle action, which indicates that the results are conclusive and independent of certain data constraints. Both the leader's and the follower's muscle regions profited greatly from proper DCS implementation, which was most apparent for the Erector Spinae muscles. Correct implementation of the DCS during patient transport decreased drastic statistical changes in EMG activity for the leader and the follower with exception to one case. The Latissimus Dorsi muscle action of the follower made a statistically substantial increase that is actually a benefit because these muscles are thereby being used for a pulling task rather than a lifting task to which they are poorly matched. Spinal stability is increased for the DCS operator, as seen by the drop in external oblique action (Lavender, 2004).

From the data in Table 3, it is seen that the injuries caused (hazard category) to the operators while carrying the patient down stairs reduces significantly if the cot is equipped with the DCS. In the conventional way, where the patient is carried on the cot not equipped with DCS, if the leader or the follower were to lose control of the cot, or lose their balance, serious injury can occur to the patient and the other operator. For a cot equipped with the DCS, if the leader or the follower were to lose control of the cot, or lose their balance, the operator on the opposite end can control the cot, which may cause a minimal stress to that operator. Thus, it can be said that for a cot equipped with the DCS the safety of the patient is not compromised when one of the operators loses his balance or control over the cot. Transporting a patient with a cot equipped with the DCS, over damaged steps or uneven steps can increase the stress level of the operators, but it is still safer, easier and less injury prone than the conventional way of carrying the patient down stairs. In addition, the patient has a higher comfort level when transported by a cot equipped with DCS because the distance of the litter bed from the stairs is constant.

## **CONCLUSIONS**

Through both biomechanical analysis and FMEA it is hereby concluded that the proper implementation of the Descent Control System provides benefits to both the leader and the follower technicians during patient transport down stairs, as well as to the patient being transported. The DCS has been found to reduce the action and work done by two of the main lower-back muscles during patient transport, thus increasing operator comfort. The DCS also increases operator and patient safety by keeping the stretcher system in constant contact with the ground, which reduces the potential of possible injuries during patient transport. Thus, performing patient transport using the DCS when descending stairs is more safe, ergonomic, efficient, and economical than the conventional.

## **RECOMMENDATIONS**

For future research it is recommended that other categories and variables be explored for analysis during patient transport. For example, the length of descent could be changed, the weight of the patient load could be increased, and the descent environment could be made to be more complex (with turns and landings). It is also recommended that further study and analysis be made on the action and ergonomics of DCS engagement in various environments.

## **ACKNOWLEDGEMENTS**

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