Injury Profile for Airborne Operations Utilizing the SF-10A Maneuverable Parachute

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Abstract

Purpose: The purpose of this investigation was to determine the injury profile of the steerable, SF-10A, static-line parachute. **Methods:** The investigation evaluated prospectively 972 low-level static-line training jumps for major injuries that required CASEVAC from the drop zone and for minor injuries that allowed the jumpers to continue with their training mission. **Results:** The investigation found overall injury rates to be 8.23 per 1000 jumps, with 2.03 per 1000 jumps requiring CASEVAC. **Conclusions:** Overall attrition rates of the steerable SF-10A parachute were below those of previously reported non-steerable parachutes, suggesting further evaluation is warranted of maneuverable parachutes in all military services.

Introduction

The U.S. military uses airborne forces to conduct decisive, short-notice, forced entry operations deep into enemy territory.[1] In Marine reconnaissance units, this special insertion technique focuses on the clandestine insertion of personnel in order to execute their primary mission. Although military parachuting makes up a small component of the overall combat mission, the potential for injury or attrition at the drop zone (DZ) could severely impact the ability of a reconnaissance team to complete their assigned task. Military parachuting programs are designed to maintain the highest degree of proficiency and safety, despite adverse conditions such as unknown terrain, low-light conditions, and high-wind environments. The ability to recognize injury profiles and reduce casualty rates allows for the preservation of the fighting force with the ultimate goal of mission accomplishment.

Military airborne missions vary from training jumps into a known daylight DZ, to night jumps with combat equipment into unfamiliar terrain. In addition, a variety of countries and the Services use several types of free-fall and static-line parachutes, making a comparison of injury profiles difficult. Injury rates for military parachuting are commonly reported as three to twenty-four casualties per thousand jumps,[2-8] a broad range that could significantly impact mission capability. Dupuy studied 162 World War II and 53 post-World War II combat operations and determined a 1% casualty rate for daytime airborne operations, and a 2% casualty rate for nighttime airborne operations.[9] In comparison, recent data collected from combat static-line airborne missions in Operation Enduring Freedom (OEF) and Operation Iraqi Freedom (OIF), by the 75th Ranger Regiment, showed a 12% injury rate among 634 jumpers, with 4% requiring casualty evacuation.[10] Given the relatively rare use of this unique insertion technique, injury profiles, and attrition rates for airborne operations are not consistent nor well documented.

The purpose of this study was to prospectively evaluate the injury profile of the SF-10A steerable round parachute, used by the U.S. Marine Corps and other Special Operations units, in static-line airborne operations. Table I outlines the specifications of the SF-10A, a commercial, off-the-shelf parachute designed for greater maneuverability and softer landings at high altitude.[11]

Table I. SF-10A Manuverable Troop Parachute System	
Nominal Diameter	9.8 Meters
Number of Gores	28
Canopy Material	Low Porosity Nylon
Suspension Line Length	6.5 Meters
Suspension Line Tensile Strength	1780 N (400 lbs)
Time for 360 Degree Turn	4 Seconds
Assembled Weight	29 lbs
Maximum Exit Weight	400 lbs
Minimum Exit Altitude	500 ft AGL
Maximum Exit Velocity	150 KEAS
Rate of Descent (min/max weight)	10.5-15 ft/sec @ sea level

Patients and Methods

The study collected data prospectively for all injuries in military low-level, static line jumps conducted between October 2008 and January 2009 at Al Asad Air Base, Iraq, by a U.S. Marine Reconnaissance unit. The unit performed a total of 972 static-line jumps using the SF-10A parachute. The servicemembers were medically qualified for airborne operations and previously attended the U.S. Army Airborne School. Of the 972 total jumps, 361 were performed as a transition course to the SF-10A parachute for jumpers who had not been exposed to this particular rig. The transition course consisted of a six-hour "ground school" followed by a slick jump (i.e., one with no combat equipment) at 2,500 feet above ground surface, a slick jump at 2,000 feet, and a combat equipment jump at 1,500 feet. Since these students were unfamiliar with the SF-10A parachute, the study considered them to be "inexperienced" jumpers. "Experienced" members, those who had previously completed the transition course, performed the remaining 611 jumps at 1,250 feet.

Aircraft used during the study varied depending upon availability. The C-130J fixed-wing aircraft performed the majority of the missions and accounted for 506 jumps. Marine Corps CH-53 helicopters accounted for 271 jumps. The remaining 195 jumps occurred from the tilt-rotor MV-22 Osprey. Jumpers performed all exits from the rear tailgate of the aircraft on all of the aviation platforms.

The study examined jumps into two separate DZs with similar characteristics. Both DZs measured 500 by 700 meters (1640 by 2300 feet) and were free from water obstacles or trees. The terrain was flat and consisted of hard-packed dirt with occasional small rocks. The perimeter was lined with fences and hardened concrete structures. Elevation at both landing zones was 600 feet above mean-sea level (MSL).

Daylight conditions were present for 505 jumps, while 467 jumps took place in low-light environments. With respect to gear configuration, the jumpers used combat equipment for 385 jumps, whereas the slick configuration made up the remaining 587 jumps. Table II shows a summary of collective mission profile data.

Table II. Low Level Static Line Mission Profiles	
Illumination	
Daylight	505 jumps (52%)
Lowlight	467 jumps (48%)
Experience Level	
SF-10 Transition Course	361 jumps (37.1%)
Prior Course Graduates	611 jumps (62.9%)
Altitude	
2500 ft AGL	60 jumps (6.2%)
2000 ft AGL	76 jumps (7.8%)
1500 ft AGL	225 jumps (23.1%)
1250 ft AGL	611 jumps (62.9%)
Aircraft Type	
C-130	506 jumps (52.1%)
CH-53	271 jumps (27.9%)
MV-22	195 jumps (20.1%)
Gear Configuration	
Slick	587 jumps (60.4%)
Combat Equipment	385 jumps (39.6%)

Uniforms and protective equipment were not controlled. Participants had their choice of desert camouflage uniform or desert flight suit for primary protection. The study plan required the jumpers to wear Modular Integrated Communications Helmets (MICH) with strobe lights attached to the posterior aspect of the helmet during low-light operations. Eye protection and glove use was compulsory, but brand and type differed among individuals. Elbow and knee-pads were optional and rarely used. Marine Corps combat boots, without the use of protective ankle braces, were required. Combat equipment, when configured, varied between individuals, with total weight of jumper and gear less than 400 pounds.

The study classified as injured any patient that presented to the military surgeon for care related to airborne operations, regardless of whether the surgeon placed them on a light or limited duty status. Demographic information collected on injured patients included age and experience level. The study also documented operational characteristics such as light level, aircraft used, gear configuration, exit altitude, and ground wind speed. Severity of injury was classified as "minor" if the patient was capable of performing a combat foot patrol despite their injury, and "major" if the patient required CASEVAC from the point of injury. The study noted the injury diagnosis and involved region of the body, as well as the estimated root cause of the incident.

Results

The study considered eight patients as injured during the series of 972 jumps using the SF-10A parachute. This translates to an overall rate of 8.23 injuries per 1000 jumps. Among the eight injuries, two were considered "major," resulting in a rate of 2.06 per 1000 jumps that required CASEVAC from the point of injury. Six injuries were considered "minor," allowing for a rate of 6.17 per 1000 jumpers to complete the training mission despite their injuries. While the jumpers wore reserve parachutes, none activated them during this particular series. No fatalities or significant malfunctions occurred.

The mean age of injured patients was 29.1 years. Four of the injured patients (50%) were between 20- and 29-years-old, three patients (37.5%) were between 30- and 39-years-old, and one patient (12.5%) was greater than 40-years-old.

Three of the injured jumpers (37.5%) were "experienced," having previously completed the transition course, while five of the jumpers (62.5%) were "inexperienced" with the SF-10A parachute.

Of the aircraft used when injuries occurred, three involved the C-130J (37.5%), three occurred with using the CH-53 (37.5%), and two with the MV-22 (25%). Five casualties occurred during low-light levels (62.5%), while three took place during daylight

(37.5%). Six of the injured (75%) wore combat equipment while two of the injured (25%) used the slick configuration. High wind speed (10+ knots) was present in the jumps with four injuries (50%), to include both major injuries. Wind speed was moderate (5-10 knots) in the jumps with two injuries (25%) and light (0-5 knots) in the jumps with the other two injuries (25%).

Location of the injury involved the upper leg or knee in four injuries (50%), the head or neck in three injuries (37.5%), and the ankle in one injury (12.5%). Root causes of the injuries for the casualties included improper parachute landing falls (PLFs) by four patients (50%), landing hazards for two patients (25%), improper exit technique for one patient (12.5%), and improper gear configuration for one patient (12.5%). Table III presents the injury summary profile.

Table III. Injury Profiles	
Overall Injury Rate	8.23 per 1000 (0.8%)
Major, Requiring CASEVAC	2.06 per 1000 (0.2%)
Minor, Completed Mission	6.17 per 1000 (0.6%)
Age of Injured Patients	
20-29	50.0%
30-39	37.5%
40+	12.5%
Injury by Experience Level	
Experienced	37.5%
Inexperienced	62.5%
Injury by Aircraft	
C-130	37.5%
CH-53	37.5%
MV-22	25.0%
Injury by Configuration	
Combat Equipment	75.0%
Slick	25.0%
Injury by Wind Speed	
10+ knots	50.0%
5-10 knots	25.0%
0-5 knots	25.0%
Root Cause of Injury	
Poor PLF	50.0%
Landing Hazard	25.0%
Exit Technique	12.5%
Gear Configuration	12.5%

Discussion

Although the overall injury rate of 0.8% in this particular series falls within previously reported rates of 0.2% to 2.4%, it is significantly less than the 12% injury rate published by Kotwal, et al., for recent low level, static-line combat jumps in OIF and OEF.[10] Several factors likely contributed to the difference in injury rates. Primarily, this study followed training missions that occurred without concern for the logistical and operational requirements of combat missions, not to mention the intangible psychological stressors related to "real world" missions. Also, the SF-10A parachute system is designed to increase the jumper's maneuverability and decrease the rate of descent (when compared to the T-10C, non-steerable parachute). This may have allowed SF-10A jumpers to avoid DZ on obstacles, steer the parachute into an upwind landing direction, and attain a better PLF position, resulting in fewer casualties. Of note, Kotwal's study reported no injuries for the jumpers who used a C-130 tailgate exit (versus the side-door exit technique). This is consistent with findings in prior studies of injury profiles,[4,7] and the authors believe the exclusive use of tailgate exits in this study likely contributed to lower casualty rates. Further investigation on the use of tailgate versus side-door exits could lead to significant reductions in the attrition rate during static line airborne operations.

Several studies examined environmental risk factors, such as wind, landing hazards, altitude of the drop zone, and light levels, that affect the risk of injury during airborne operations.[3,10,12-14] Half of the total injuries, and both injuries that required CASEVAC in this study, occurred with wind speeds in excess of 10 knots. While several studies documented the association between increased injury rates and increased wind speed,[4,14] there is also evidence that injury rates increase with winds *below* five knots due to poor PLF techniques in the absence of relative motion.[6,12] One possible explanation for the lack of low-wind injuries with SF-10A parachute is the ability to flare and control the amount of lateral movement with toggles on this new parachute.

Various studies closely linked illumination and visibility to injury rates. While attrition rates typically double during low light conditions,[4,9,14] military commanders of a reconnaissance unit are more likely to utilize night jumps due to the clandestine nature of their mission. During low levels of illumination, identification of landing hazards becomes difficult. In addition, judgment of lateral motion is impaired during low-light conditions, possibly affecting PLF techniques.

The increased risk of injury with high elevation DZs is likely multi-factorial.[7] The decreased air density above 5,000 feet (above MSL) requires aircraft to maintain a higher airspeed, resulting in a greater opening shock. This increased opening shock may rupture gores and panels in the parachute, lead to suspension line failure or cause traumatic injury to the jumper. The decreased air density also causes the rate of descent to increase. The SF-10A parachute with 400 pounds total weight increases from 15 feet/second at sea level to 17 feet/second at 9,000 feet MSL.[11] While an important consideration for operational planning purposes, this effect was not evaluated in this study design with a drop zone elevation at 600 feet MSL.

One must also consider the effect of total weight and combat equipment configuration. This study found a significant increase in injury rates and severity when jumpers wore combat equipment. For the SF-10A parachute, descent rates at sea level increase from 10.5 feet/second at 200 pounds total weight, to 15 feet/second at 400 pounds.[11] Since impact rate is known to increase with excessive weight, commanders should ensure that airborne personnel wear only mission-essential equipment. From an ergonomic standpoint, the SF-10A parachute requires the jumper to shift the individual toggle controls from two hands to one hand at 100 feet above the ground in order to use the newly freed hand to lower the combat equipment prior to impact. After the jumper lowers the equipment, they place both hands back on the individual toggles to prepare for landing. Individual jumpers report perceptual narrowing with task saturation during a critical time in the landing sequence. Jumpers must practice this muscle movement and reinforce it through training in order to maintain the maneuverability characteristics of the parachute upon landing.

Several published articles have debated the usefulness of the parachute ankle brace (PAB) in preventing commonly reported ankle injuries.[3,4,15,16] The PAB was neither available nor required during our study. Although we suspect the maneuverability of the SF-10A parachute decreased the rate of ankle injuries, the one ankle injury we observed (0.1%) was well below the non-PAB injury rates of 0.5% previously published.

Conclusions

As military parachuting equipment and design continue to evolve, injury profiles and patterns must be re-evaluated and documented. These results should be presented to commanders during the planning process to assist with their operational risk assessment for inherently dangerous missions. Research and development should focus on known injury risk factors to procure equipment that decrease the rate of descent, decrease the weight of mission-essential gear, and increase the maneuverability of parachutes.

Current injury data from the various branches of military service are disjointed with sporadic reporting in the medical literature. All services should consider using a centralized data repository that tracks comprehensive injury profiles – not just significant mishaps or deaths. This evolving set of data will assist medical planners to best place limited medical assets in the unique and relatively rare case of combat airborne operations. The Services should place further emphasis on finding and type classifying a common, steerable, static-line parachute in hopes of decreasing overall injury and attrition rates.

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