NECK INJURY RISK FROM HELMET MOUNTED DEVICES DURING PARACHUTE OPENING

B. J. McEntire*, F. T. Brozoski, N. Alem
U.S. Army Aeromedical Research Laboratory, Aircrew Protection Division
Fort Rucker, Alabama 36362-0577

ABSTRACT

Parachute opening shock tests were conducted with an instrumented test manikin to measure and record transmitted neck loads. The standard paratrooper helmet, as well as two developmental helmet systems, were fitted to the manikin head. These two systems alter the head-borne weight and center of mass from the standard helmet, potentially increasing the risk of acute neck injury during parachute opening. A total of 52 trials were successfully conducted. A statistically significant increase ($p<0.05$) in the neck flexion moment was found in one of the two developmental systems, but peak moments were below published neck injury thresholds.

1. INTRODUCTION

The U.S. Army has the mission to conduct mass airborne operations. To a large extent, a successful airborne operation is dependent on the ability to insert combat ready troops into the objective injury-free. Parachuting exposes paratroopers to unique injury risks. Some of these risks are associated with the dynamics of parachute opening shock (POS) and the parachutist's landing fall, (Wehrly, 1987; Pascal et al., 1990). During POS events, the neck is potentially vulnerable because the head is likely to flail as inertial loads overcome voluntary muscular control. These inertial loads are resisted by the neck bone and soft tissue structures. The addition of head- or helmet-mounted devices could increase the transmitted neck loads during airborne operations, increasing neck injury risk.

Soft tissue injuries such as neck strains and sprains could affect soldier performance. Typical symptoms of acute neck strain and whiplash injuries include stiffness, headache, neck and shoulder pain, and neurologic dysfunctions such as visual disturbance, dizziness, and impaired concentration (Sturzenegger et al., 1994). More serious injuries could have greater operational impact as well as disability and occupational implications.

The objective of this study was to assess the injury risk of inertial neck loads produced during POS while wearing helmet configurations characteristic of future combat helmet ensembles.

2. METHOD

An instrumented test manikin (figure) was repeatedly exposed to parachute openings while encumbered with different head-borne mass conditions. The manikin was a Hybrid III type dummy modified with an articulated spine and internal data acquisition system. Electronic data were recorded at a sample rate of 4000 Hertz and filtered in accordance with SAE-J211 (Society of Automotive Engineers, 1995). A software program culled the peak values (maximums and minimums) from the filtered data signals. Video recordings of the manikin's aircraft exit and subsequent parachute opening were reviewed and the neck load data were screened to identify occurrences of the parachute riser snagging on the head and helmet. Exits where a head/helmet snag occurred were excluded from the data set as the loads transmitted through the riser contaminated the pure inertia loads under evaluation.

Figure. Instrumented manikin configured with T-10 parachute and LW-V1.0 helmet.

Three different head-borne mass conditions were evaluated (table 1). The standard paratrooper helmet (the airborne PASGT) was used as a comparison baseline. Two developmental systems were tested. One was the Individual Combat Identification System (ICIDS), which was attached to the PASGT helmet. The second was the Land Warrior version 1.0 (LW-V1.0) helmet system. Two separate test trials were completed. The first trial assessed the ICIDS and standard PASGT helmets at 110 knots indicated airspeed (KIAS). The second assessed the LW-V1.0 and standard PASGT helmets at 120 KIAS.

Table 1.
Helmet Weight and Center of Mass Location.

Test helmet	Weight (kg)	x-axis	y-axis	z-axis
PASGT, med	1.618	-1.67	0.00	7.12
ICIDS, med	1.979	-3.00	-0.10	6.41
LW-V1.0, lg	1.991	-1.78	0.01	8.13

Note: Units are centimeters for center of mass locations, measured relative to the head anatomical coordinate system.

An Army UH-60A Black Hawk helicopter was used to obtain the desired release altitude (500 feet above ground level) and airspeed. A standard T10 parachute (circular static line deployed) was used for all exits.

The data channels of interest for this study included the upper neck forces and moments. Two data analysis methods were used. First, a comparison of means was conducted to determine if the addition of the head-mounted weights produced a statistically significant difference ($p<0.05$) in the transmitted neck loads. Within each group, a one-way analysis of variance was used to compare the means and standard deviations. Second, the peak neck forces and moments were compared to the neck injury assessment reference values (IARVs) established in the Federal Motor Vehicle Safety Standard (FMVSS) 208.

3. RESULTS AND DISCUSSION

The UH-60 Black Hawk proved to be an efficient method to conduct multiple aircraft exits, allowing 15-minute test cycles. Seven of 59 helicopter-exit data sets were eliminated from the analysis due to signal contamination from riser snag. The peak values for the upper neck moments and forces were used to calculate the mean and standard deviations (table 2). For the ICIDS comparison, only neck flexion (+My) produced a significant difference ($p<0.05$) from the standard paratrooper helmet. No significant differences were found between the LW-V1.0 helmet and the standard paratrooper helmet, though neck flexion was close ($p=0.06$). In this case, the LW-V1.0 helmet flexion moment was lower than the standard helmet. For all tests, the peak force and moment values were well below the FMVSS neck injury assessment reference values. Analysis of the combined neck loading injury criteria (Nij) is planned for FY03.

The FMVSS IARVs have been established for occupant safety in ground vehicle crash impacts and may be too high to detect or suggest lower severity neck injuries (e.g., strain, sprain). Low severity neck injury criteria are being reviewed and researched for potential application to the parachuting environment.

4. CONCLUSIONS

The ICIDS configured helmet produced a statistically significant increase in neck flexion moment ($p<0.05$) over the standard paratrooper helmet, although the peak flexion moments remained below the published neck injury thresholds. Both the ICIDS and Land Warrior helmet configurations were recommended for operational testing. The FMVSS neck injury criteria are being evaluated for suitability to the airborne environment and new criterion evaluated.

ACKNOWLEDGEMENTS

The authors acknowledge the critical contributions of many individuals who participated in this successful research effort, including electronic engineers and technicians, aviators and aircrew, photographers, research support soldiers, and airborne operational support personnel from Fort Bragg, NC. The PM-Soldier, Future Objective Warrior Program Office, and the Medical Research and Materiel Command provided funding for this effort.

REFERENCES

Federal Motor Vehicle Safety Standard 208: Occupant Crash Protection, 49 CFR 571.208, October, 2001

Pascal, C., Palmer, R., Shanahan, D., Haley, J., 1990. Evaluation of the Head Injury Hazard During Military Parachuting, USAARL Report 90-6.

Society of Automotive Engineers, 1995. Recommended Practice J211, Instrumentation for Impact Test – Part I – Electronic Instrumentation, Warrendale, PA

Sturzenegger, M., Radanov, B., Di Stefano, G., 1994. Presenting symptoms and signs after whiplash injury: The influence of accidental mechanisms. Neurology, Vol. 44

Wehrly, David. 1987. Low Altitude, High Speed Personnel Parachuting: Medical and Physiological Issues. USAARL Report 87-3.

Table 2.
Parachute Opening Shock Neck Loads.

Neck load variable	FMVSS IARV	Trial 1, 110 KIAS					Trial 2, 120 KIAS				
		PASGT (n=14)		ICIDS (n=13)		p-value	PASGT (n=14)		LW-V1.0 (n=11)		p-value
		mean	std dev	mean	std dev		mean	std dev	mean	std dev	
Lateral bend, +Mx	None	127.8	75.8	142.6	85.2	.64	146.7	86.6	123.3	71.6	.48
Lateral bend, -Mx	None	-146.6	60.7	-148.6	80.2	.94	-149.4	57.8	-190.5	87.4	.17
Flexion, +My	1681	104.6	51.2	184.4	123.1	.04	161.4	57.1	126.7	53.9	.06
Extension, -My	505	-73.4	50.1	-59.7	36.1	.42	-84.1	42.0	-55.7	22.9	.14
Forward shear, +Fx	697	83.4	31.7	73.1	38.2	.45	64.3	36.0	41.2	30.2	.10
Rearward shear, -Fx	697	-88.8	23.2	-93.7	35.7	.67	-75.5	25.7	-73.0	21.2	.80
Lateral shear, +Fy	697	39.0	14.7	39.5	30.1	.95	39.8	11.8	40.2	35.5	.97
Lateral shear, - Fy	697	-54.7	19.4	-58.2	28.1	.71	-48.6	20.4	-61.8	24.9	.16
Tension, +Fz	742	179.3	88.7	177.8	81.1	.96	139.7	58.3	118.8	58.0	.38
Compression, -Fz	900	-39.9	34.0	-52.2	29.2	.33	-45.5	22.1	-39.5	19.7	.49

Note: Units are inch-pounds for bending moments and pounds for forces