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USAARL REPORT NO. 71-9

MEDICAL AND PHYSIOLOGIC EFFECTS OF EJECTION AND PARACHUTING AN OVERVIEW

By

Stanley C. Knapp, LTC, MC, FS

August 1970

U. S. ARMY AEROMEDICAL RESEARCH LABORATORY

Fort Rucker, Alabama

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ABSTRACT

Design requirements for ejection seats and personal survival equipment sometimes omit as a criteria - man's physiologic and psychologic limitations.

Man's ability to come through the ejection and parachute descent sequences uninjured is influenced directly by the design of the equipment and his experience in the techniques of proper use.

Many limiting physiologic factors must be considered. Response to multiple accelerations in multiple axes, wind blast, effects of temperature extremes, anthropomorphic problems, and neuromuscular response are among the factors discussed.

Engineers will find a knowledge of human factors vital to the design of seat restraint systems, cushions, accessory packs, control placement, catapults, the parachute, and etc.

This broad overview reviews significant literature on sport free fall, military static line, HALO, and ejection parachuting statistics.

Modes of injury and morbidity during ejection and parachuting are detailed.

APPROVED: ROBERT W. BAILEY
Colonel, MSC
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MEDICAL AND PHYSIOLOGIC EFFECTS OF EJECTION AND PARACHUTING AN OVERVIEW

INTRODUCTION

Man's personal use of the parachute in the space age is basically as it historically evolved. He uses it for pleasure and sport. He uses it as a means of surviving a hostile environment, namely disabled aircraft, spacecraft, or other flying vehicles; and he uses it as a means of transportation, primarily in the military.

The medical factors of parachuting are influenced or modified by the reason-for-use. Equipment, techniques, hazardous variables, and the acceptable envelope for safe usage vary widely in these three broad categories. Two common denominators do exist:

1. When the effects of parachute use have their end point in biomechanical injury, the causative factors are essentially the same no matter why the parachute was used.

2. The success of parachute use will depend directly on the man-equipment interface. Equipment adequate for the task but difficult to use and requiring human intervention may pose an unacceptable interface. Automation and simplicity may be design factors that ensure success if proper human response for use of the machine cannot be predicted. Appropriate human response is influenced by experience, training, instinctive knowledge and use of correct techniques, and the ability to avoid and avert unwanted variables.

CATEGORIES OF MEDICAL FACTORS

For this paper the major areas of medical significance in parachuting are grouped into the categories of psychological, physiological, anatomical, and biomechanical.

PSYCHOLOGIC

The psychological parameters include decision making processes, the initiation of canopy deployment or ejection, fear, anxiety, man's innate "coolness-in-a-difficult-situation", and the overall effect parachuting has on a man's psyche. If the system works poorly he may elect not to rely on it during some future event.

PHYSIOLOGIC

This category includes:

1. Physical work involved.

2. Rapid changes in ambient pressure during ascent and descent with associated problems of ear barotrauma, trapped gas and evolved gas syndromes.

3. Positive pressure breathing at high altitudes.

4. Hypoxia.

5. Exposure to low ambient temperature.

6. Wind blast.

7. Acceleration effects on the body's cardiovascular system.

8. Psychomotor response to action-requiring stimuli.

ANATOMIC

Anatomical factors include parachute sizing for correct fit. Anthropomorphic factors influence cockpit seating, control placement, and ease of escape. Height and weight influence biomechanical injury. Pre-existing or congenital defects or derangements provide weak anatomical links in the system.

BIOMECHANICAL

Biomechanical factors are intimately involved with short term accelerations applied to the human body. Ejection, opening shock, man-seat separation, and ground impact contribute most of the biomechanical injuries. Dragging injuries due to a failure or inability to release the parachute after landing are in this category; as are the resulting avulsing, crushing, and other trauma resulting from parachutist-equipment entanglements.

THE PARACHUTE SEQUENCE

We must define the parachute sequence. It is useful to consider the sequence extending into a period antecedent to aircraft exit and an indefinite period following ground contact which may or may not end with the collapse of the canopy. The sequence can be divided into eight phases. This closely conforms to the phases with which the parachutist is familiar as a result of his training. They are:

1. The pre-jump phase.
2. Jump (ejection) phase.
3. Free fall.
4. Decision or deployment - initiation phase.
5. Opening shock.
6. Parachute descent.
7. Ground impact.
8. Post impact phase.

PRE-JUMP

The general physiological and psychological condition of the parachutist is important during this phase. Pre-existing illness, especially of the cardiovascular and respiratory systems, old fractures, sprains, or general poor physical conditioning may make success marginal. Congenital or acquired anatomical deformities of the vertebral spine of any type may make the individual unable to stand the accelerative forces of opening shock and ground impact. Sport, free fall, and military HALO (High Altitude Low Opening) activities demand individuals that are psychologically well balanced.[1,2] Persons with pre-morbid ideology, depressive episodes, suicidal tendencies, phobias of great heights, counterphobic behavior, or other psychoneuroses are unfit candidates. A lack of confidence in the equipment or ability to use it correctly, significantly jeopardize success.

An unusually loose harness because of improper donning and fitting can cause dynamic overshoot during the decelerative force of opening shock and transmit these amplified forces to tissues beneath the harness as well as to the entire body. Ejection seat integrated parachute-restraint harnesses must provide adequate restraint not only for the ejection phase but for possible crash impact and retention during aerobatics. The harness must not be too tight or there is a danger of neurocirculatory bundle compression with resultant discomfort, peripheral peristhesias, decreased peripheral neuromotor functioning as well as decreased lung ventilation.[1] Twisted or misrouted straps will not distribute opening shock forces evenly. Attention to the helmet, goggles, clothing, gloves, and various attached accessory kits, can eliminate a serious injury during some later phase. Significant environmental factors may be present.[3] They are:

1. Decreased partial pressure of ambient oxygen with the danger of hypoxia. Inadequate, malfunctioning, or missing oxygen support equipment creates a serious situation. This problem is common with inexperienced sport parachutists trying for higher and higher altitudes without proper oxygen equipment.

2. Fire, toxic fumes, or smoke can incapacitate a pilot.

3. Rapid decompressions at high altitudes may cause expansion of gases trapped in hollow organs causing pain. Gases evolved from the blood or other body fluids may produce bends or other decompression sickness.

4. Exposure to the extreme cold of high altitude.

5. High noise levels.

A disabled aircraft may rotate or tumble wildly subjecting the pilot to disabling G forces. He may not have the strength to overcome these forces to initiate ejection or bail out.

JUMP (EJECTION) PHASE

Significant biomechanical injury occurs during mass exit military low altitude static line jumps.[4] The very existence of a static line or umbilical cord between the parachutist and the airplane provides a device in which some unfortunate soul will become entangled. Upper extremity crushing injuries are a frequent result. Proper body positioning, and a correctly executed exit from the aircraft will assist in the correct deployment of his parachute, the avoidance of entanglements with fellow paratroopers, and the avoidance of aircraft structures. A "hung-up-jumper" is unusual. When it occurs it can result in serious injury secondary to wind blas. and slip stream flailing of the parachutist against the aircraft fuselage. Escape from this situation requires not only an alert state of mind but freedom from serious injury. Parachutist retrieval into the aircraft is not usually successful. Cutting the parachute loose deprives the man of his main canopy, places the decision and the opportunity to use his reserve in a marginal envelope of low altitude and minimal time, and often over unimproved and hazardous terrain.

The sport or HALO parachutist usually has considerable control over this phase. High levels of anxiety have been reported as well as hyperventilation and rather prolonged periods of rapid heart rate.[5] Because of the altitudes, hypoxia must be prevented. Wind blast upon aircraft exit will be of little importance averaging 60-130 knots IAS. Body position is a key factor in achieving stabilization and preventing tumbling and spinning during free fall.

We cannot explore in detail the ejection-parachute sequence of escape from ejection seat equipped disabled aircraft. In the period 1950 through 1959, the United States Air Force had an 81% success rate. The period 1960 through 1968 saw an 85% success rate.[6]

The decision to eject is a most compliated one. Chubb[7] demonstrated that on occasion the better the system the poorer the success rate. If the pilot instinctively feels that his system has a limited success envelope, he may eject early without attention to aircraft position, airspeed, or presence of tumbling. He can of course have so little confidence in the system that he rides-it-out. McQuire[8] at the United States Air Force School of Aerospace Medicine in a personal study on the psychology of ejection initiation feels that confidence in the parachute system is a major role in the decision process. Collins, et at,[9] in a four year survey of USAF ejection seat escape injury experience noted that out of 835 total ejections of which 700 were successful, 11 fatalities occurred during the ejection phase. There were 88 major injuries. The major injuries are spinal fractures or dislocations due to the accelerative forces of the seat. Flailing and contact with aircraft structures cause a scattering of fractures and dislocations of the upper and lower extremities, internal, and soft tissue injuries.

Zero-zero or extreme low level ejections require special parachute systems. Improved seat trajectories through seat stabilization, rocket systems, vernier rocket attitude control systems, ballistically deployed parachutes, and ballistic opening of the canopy might improve a discouraging low level ejection success rate.

Any injury sustained during ejection will jeopardize the parachutist's ability to manually operate the parachute systems, i.e., perform "four-line cut", or assist in the parachute landing fall.

The problems of wind blast or Q forces should be mentioned even though good statistics are not available. In Collins' study, eight brain injuries were caused by Q force impact of the head against the head rest or man-seat collision after ejection. Smiley[10] reporting on the Royal Canadian Air Force ejection experience, 1962 through 1966, demonstrated that helmet loss was the single most frequent result.

Loss of helmet and oxygen mask, especially at high altitude, presents the risk of hypoxia, exposure to cold and loss of head protection on landing.

Q force values of less than 200 pounds/foot^2 have produced serious injury while calculated values of over 1000 pounds/foot^2 have caused none. Extremity flailing accounts for most of the fractures attributed to Q forces.

<u>FREE FALL AND DECISION TO INITIATE DEPLOYMENT</u>

A free falling parachutist or pilot-ejection seat combination may have delayed canopy openings exceeding 60 seconds. Terminal velocities of 660 feet/second will be reached in 33 seconds at 69,000 feet[11] and 174-180 feet/second in 12 seconds at 5000 feet.[2]

Tumbling, spinning, and unusual attitudes must be avoided. Vestibular stimulation with resultant illusions, nausea, vomiting, headache, vertigo, and disorientation can occur. Spins about the X axis and tumbling about the Y axis are especially bad.

Most man-ejection seat combinations fall in an attitude 30 degrees face forward of the Z axis. A force of 2.0 negative Gs can be developed in this attitude.[12] Flat spins of 60 RPM about the X axis can cause a condition called red out where the subject experiences a red veil being pulled over his eyes.

Velocity changes exceeding 3 RPM/second can produce blood tinged tears, cyanosis, headache, conjunctivitis, and small petechial hemorrhages about the head, neck, and mucous membranes.[12] The hydrostatic pressure of the column of blood between the axis of rotation and head can become several times normal.

Drogue stabilization chutes and gyroscopically controlled vernier seat rockets will lessen the hazard. Body positioning during free fall will prevent spins; but assumes experience, training in technique, alertness, and freedom from injury.

The reduced partial pressure of oxygen at altitudes above 10,000 feet creates the risk of hypoxia.[13] Above 40,000 feet, positive pressure breathing of 100% oxygen is necessary. Useful conscious time at 30,000 feet is 100-120 seconds and 30 seconds or less at 45,000 feet.[3] The man has impaired psychological and physiological functions in a few seconds.

Temperatures during free fall may fall to -50 degrees centigrade.[1,3] High evaporative loss from the skin secondary to low humidity and wind may produce frostbite injuries. An intact helmet, gloves, boots, and a lowered sun shield will lessen the hazard.

Kyle[14,15] reported that 34% of military sport parachuting deaths were caused by some failure to initiate the deployment of the parachute. The potential psychological reasons include disorientation, ground fixation, suicidal intent, distractions, and others. Physiologic reasons include unconsciousness due to antecedent injury, hypoxia, possible decreased cardiac stroke output of heart rates over 200, or accompanying arrhythemias.[5]

The decision to deploy the parachute at the proper altitude is one of training, experience and technique. The value and safety of automated systems for ejection seats is well known.[9] Timed or barometrically operated devices for sport free fall and HALO activities are in wide use.

THE OPENING SHOCK

Time for parachute opening is directly related to the velocity of the chute through the air. Opening shocks vary then with free fall velocity at chute opening. Since terminal velocity will vary from 660 feet/second at 70,000 feet to 170 feet/second at sea level, it is understandably appropriate not to deploy at high altitudes to avoid high G forces.

The parachutist is able to withstand accelerative changes of up to 25 Gs peak with rates of onset somewhat less than 500 Gs per second for 0.1 to 0.3 seconds in the Z axis.[3] With a properly adjusted harness, vertebral or skeletal injuries are not common. However, an unusual body attitude at opening can amplify G forces by the lever arm of the parachutist's body. Shoulder and neck injury can occur. The average parachute harness has a load bearing area of approximately 40 square inches. A 200 pound parachutist decelerated at 8 Gs will distribute the opening shock to the soft tissues beneath the harness at a force of 40 pounds/inch^2. Slack in the harness will cause potentially dangerous dynamic overshoot and G amplification.

Every attempt should be made to distribute the force of opening over a prolonged period of time. The sleeve deployed sport parachutist canopy is an excellent example of this.

THE PARACHUTE DESCENT

The parachute descent is usually uneventful. Military parachutists are always hazarded by entanglement with fellow jumpers. All parachutists are subject to unusual wind currents and thermals that can carry them into unwanted landing areas.

Parachute oscillations must either be designed out of the system or damped through some technique of the parachutist. The United States Air Force teaches and advocates that cutting four suspension lines allowing a portion of the skirt to vent trapped air, reduces oscillations and improves steerability. This author believes that all parachutes should be engineered to be steerable; and that every parachutist be taught the techniques of using this feature.

GROUND IMPACT

The parachute per se will have little effect on medical factors of the landing phase or ground impact. Development of fabrics and canopy configurations that will provide a gentle landing (less than 14 feet/second) without oscillation is optimum. Collins found that out of 700 successful ejections, 40 fatalities occurred in the landing phase. Failure of automated deployment systems, man-seat separation, canopy burning by aircraft fire or seat rockets and drownings are major contributors of these statistics. Major injuries were sustained by 60 individuals. They included fractures, dislocations, soft and internal injuries and were indistinguishable from the injuries that occurred during the ejection phase or those that occurred during the deceleration of opening shock. Spinal fractures, namely T-12 and L-1, were produced in almost equal numbers by catapult, thrust forces, and terrain impact. Tibial, fibular, and tarsal bone injuries are common.

Neel[16] in a study of 174,000 military parachute jumps found an injury rate that averaged 0.58%. This corresponds quite well with the injury rate as determined by Avner[17] and Kiel[15,18]. Neel's study included 1,012 injuries. Fractures accounted for 332, sprains 309, contusions 249, dislocations 33, fracture-dislocations 6, and 83 miscellaneous. Landing backward, in the sitting position, on one foot, during oscillation, stiff legged, or with the outstretched hands or elbows are the primary etiologies for injury. Too high a rate of descent, damaged canopies, failure of the canopy to properly deploy, man-parachute entanglements, unusual ground thermals and high ground wind velocities also contribute.

Many pilots and military personnel are injured due to failure to manually deploy survival kits and other equipment that are being carried. Automated systems as well as training in techniques are needed in this area.

POST IMPACT PHASE

The medical factors of the post impact or landing phase are primarily those of survival. High ground winds can cause dragging of the parachutists. Striking ground obstacles is known to have produced a wide spectrum of physical injury.[19] In water, the tendency is for the parachutist to be pulled under rather than plane along the surface. The retention of an adequate helmet and the wearing of floatation equipment will prevent some injuries but not all. The present quick release systems, i.e., the Capewell and Koch, have prevented many injuries. Their use, however, is not universal; and they are difficult to use when the parachutist has sustained an upper extremity injury.

SUMMARY

This has been a most broad overview of the medical problems associated with parachuting. Equipment and technique are the two primary elements of successful parachuting. The man-equipment interface by virture of its inseparable integration in this system must be simple and 100% reliable. When complex systems are required automation is probably necessary. The environmental factors of altitude, hypoxia, and cold will contribute morbidity statistics. Significant psychological considerations will enter into the successful training of parachutists as well as their ability to function within the environment and envelope of the parachute. Ground impact in an otherwise successful parachute sequence contributes the largest percentage of serious injuries.

CONCLUSION

Improving equipment through design and knowledge of the man-machine interface will lessen those injury statistics generated during the ejection, free fall and deployment phases. Improved training and techniques will help prevent those injuries that occur during the pre-jump, parachute descent, and ground impact phases.

BIBLIOGRAPHY

1. Schane, W. P., Physiologic Training of HALO Parachutists, USAARL Report 67-2, September 1966.

2. Sellich, B., "Advanced Free-Fall Techniques", Sky Diving, pp. 176-177, Prentice-Hall, 1961.

3. Gillies, J. A. ed, A Textbook of Aviation Physiology, pp. 48, 75-83, Pergamon Press, 1965.

4. Parachute Injury Records, 82nd Airborne Division, Fort Bragg. North Carolina and 1st Battalion Airborne, 508th Infantry, Fort Kobbe, Canal Zone.

5. Schane, W. P., and K. E. Slinde, Continuous EKG Recording during Free-Fall Parachuting, USAARL Report 67-7, June 1967.

6. Data on Ejection Successes compiled from Reports of the Life Sciences Group, Directorate of Aerospace Safety, The Inspector General, USAF, Norton Air Force Base, California.

7. Chubb, R. M., G. C. Brane, and R. H. Shannon, "Ejection Capability Versus the Decision to Eject", Aerospace Medicine, September 1967, pp. 900-904.

8. McQuire, T., Chief Department of Neuropsychiatry, USAF School of Aerospace Medicine, Lecture Notes.

9. Collins, T. A., C. H. Sawyer, V. J. Ferrari, Jr., and R. H. Shannon, "Five-Year Injury Experience in Escape from USAF Ejection Seat Equipped Aircraft", Aerospace Medicine, June 1968, pp. 627-632.

10. Smiley, J. R., "R. C. A. F. Ejection Experience 1962-1966", Aerospace Medicine, June 1968, pp. 619-623.

11. Walchner, O., "Parachutist's Spin Problem", Escape and Survival. Bergeret ed, pp. 10-17, Pergamon Press, 1961.

12. Courts, D. E., "Tolerance to Spinning in Ejection Escape", Aerospace Medicine, February 1966, pp. 133-135.

13. Courts, D. E., and W. R. Pierson, "Sport Parachuting and Hypoxia", Aerospace Medicine, April 1965, vol. 36, pp. 372-374.

14. Kiel, F. W., "Survey of Military Sport Parachuting Deaths", Aerospace Medicine, April 1965, pp. 360-363.

15. Kiel, F. W., "Parachuting for Sport", Journal of the American Medical Association, October 1965, vol. 194, pp. 264-268.

16. Neel, S. H., "Medical Aspects of Military Parachuting", Military Medicine (Then The Military Surgeon), February 1951, vol. 108:2.

17. Avner, R. A., Expected Injury Rates for Experimental Airborne Operations, USAARL Report 66-7, June 1966.

18. Kiel, F. W., "Hazards of Military Parachuting", Military Medicine, May 1965, vol. 130, pp. 512-521.

19. Chubb, R. M., E. C. Lentz, and R. H. Shannon, "Correlation of Parachute Landing Injuries and Surface Wind Velocities", Aerospace Medicine, October 1964, vol. 35, pp. 962-965.

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Many limiting physiologic factors must be considered. Response to multiple accelerations in multiple axes, wind blast, effects of temperature extremes, anthropomorphic problems, and neuromuscular response are among the factors discussed.

Engineers will find a knowledge of human factors vital to the design of seat restraint systems, cushions, accessory packs, control placement, catapults, the parachute, and etc.

This broad overview reviews significant literature on sport free fall, military static line, HALO, and ejection parachuting statistics.

Modes of injury and morbidity during ejection and parachuting are detailed.

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