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PHYSIOLOGICAL TRAINING OF HALO PARACHUTISTS

By

W. P. Schane, LTC, MC

SEPTEMBER 1966

U. S. ARMY AEROMEDICAL RESEARCH UNIT
Fort Rucker, Alabama

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ABSTRACT

This report will review the environment in which a HALO parachutist operates, will indicate some areas in training which deserve special attention, and will make some specific operational recommendations which, if adopted, would reduce the possibility of injury or disease caused by the man-environment interaction.

APPROVED: ROBERT W. BAILEY
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Commanding

PHYSIOLOGICAL TRAINING OF HALO PARACHUTISTS

INTRODUCTION

Physiological training must prepare the HALO (High Altitude, Low Opening) parachutists for a wide variety of environmental hazards which relate to (1) reduced total atmospheric pressure, (2) reduced partial pressure of O_2, (3) cold exposure, and (4) the necessity to prepare for these hazards at ground level. In the training of pilots, the thought is always present that the student is, in most cases, being prepared to cope with potential threats which probably never will arise. The thought in training HALO parachutists must be that the threats will in fact be faced during each jump. The man must be virtually self-sufficient since his communication with the aircraft crew, his jumpmaster, and his fellow-jumpers is markedly restricted by his equipment and by the ambient environment. In free-fall, of course, he is highly isolated, and can rely upon no one but himself for survival. Because of these difficulties, the physiological training of HALO parachutists must be conducted differently than the training of pilots or of jet aircraft passengers.

This report will review the environment in which a HALO parachutist operates, will indicate some areas in training which deserve special attention, and will make some specific operational recommendations which, if adopted, would reduce the possibility of injury or disease caused by the man-environment interaction.

PHYSIOLOGIC STRESSES

1. The physiologic stresses imposed upon a HALO parachutist in order of their appearance on an average summer day are:

a. Some initial physical exertion associated with:

(1) Loading parachutes and gear aboard trucks at the issue area.

(2) Off-loading parachutes and gear at the aircraft.

(3) Donning of parachutes.

(4) Loading aboard the aircraft.

b. Overheating due to:

(1) Warm ramp temperature.

(2) Heavy, warm clothing worn to protect against cold injury during free-fall.

(3) Exertion of donning parachutes and loading aboard the aircraft.

c. Restricted pulmonary ventilation due to tight fitting clothing and harness. Studies in this laboratory indicate that under some conditions vital capacity may be diminished by 11% due to restrictions imposed by a standard free-fall parachute harness.

d. Cooling of ambient temperature to a comfortable level on climb-out.

e. Rapid ascent, 4,000 - 30,000 feet over a 1 minute interval 20 minutes prior to jump.

f. Oxygen breathing. 20 minutes prior to exit, cabin pressurization is discontinued; jumpers then go onto oxygen, using a dilutor-demand regulator.

g. The possibility of dysbarism.

(1) Trapped gas in:

(a) ears

(b) sinuses

(c) gut

(2) Evolved gas:

(a) creeps

(b) bends

(c) chokes

(d) neurocirculatory collapse.

h. Hyperventilation - stimulated by:

(1) Mask breathing

(2) Anticipatory excitement

(3) Positive pressure breathing.

i. Chilling. Six minutes prior to exit, the ramp and side doors are opened to permit visual guidance of the aircraft over the proposed exit point. During this period the jumpmasters are exposed to the outside temperature (which may range from -20°C to -67°C, depending upon jump altitude and local weather conditions) and severe wind chilling as they spot. Jumpers seated aft of the wheel wells also are exposed to outside temperatures and significant wind chill. Those jumpers seated forward of the wheel wells are protected to some extent from both cold and wind chill. Measurements performed by this laboratory in a C-130H showed wind velocities in the jump door equal to the indicated air speed of the aircraft (generally 130 kts during a jump run). Wind velocity in the center of the ramp with doors open and ramp level were measured at 60 kts during a simulated jump run at 130 kts IAS.

j. High noise levels, which occur in the cargo compartment when the doors and ramp are open. Measurements performed by this laboratory showed mean noise levels in the C-130 during a simulated jump run to be 108 db just forward of the jump doors, and 113 db on the ramp. All readings were made with both jump doors open, the tail door up and the ramp level. Appendix I shows the distribution of this noise by sound spectrum analysis.

k. Positive pressure breathing, with its associated hazards:

(1) Hyperventilation.

(2) Venous stasis.

l. Chilling. Upon exit, each jumper is exposed to the outside temperature and wind of 120-150 knots.

m. Essentially 0 G for the first twelve seconds of free-fall.

n. Tachycardia 158-204 (one standard deviation from a 178 mean) beats per minute throughout free-fall and for 10-15 minutes after parachute opening[1].

o. Possible centrifugation about some body axis in cases of instability in free-fall.

p. Rapid re-compression from 30,000 feet to 2500 feet over a 2 minute period with its associated trapped gas problems.

q. Negative acceleration of three G's upon parachute opening.

r. Overheating due to:

(1) Warm ambient temperature at lower altitude.

(2) Heavy clothing worn to protect against cold injury during free-fall.

(3) Exertion of canopy control, landing, field rolling the parachute, and getting to cover.

s. Negative acceleration of three G's on ground contact.

t. Exertion of mission accomplishment.

In the training situation, these 20 stresses are compressed into about a 90 minute period, indicating that although none is experienced for any long period, there often are periods of multiple stress, and that changes often are rapid.

EMPHASIS IN TRAINING

During the period after cabin pressurization is discontinued the jumper is isolated from his fellow jumpers.

a. Almost all of his skin is covered, which prevents visual inspection for cyanosis, pallor, erythema, frost-bite, etc.

b. High ambient noise levels, the O_2 mask, and helmet attenuation prevent voice communication.

c. There is no electronic communication between jumpers.

Therefore each parachutist should be prepared to care for himself and his equipment without assistance. He must understand principles of hypoxia, dysbarism, acceleration, the physics of gases, and first echelon equipment maintenance, so that he can rapidly trouble-shoot difficulties in his own performance or in the performance of his equipment, and correct minor difficulties on the spot.

The following comments, though not encyclopedic, indicate areas where emphasis in training is essential.

a. Physics.

(1) The basic gas laws. Confusion commonly occurs because the jumper does not understand the principles involved in the basic gas laws. Three examples will be given:

(a) The jumper frequently finds that he can breathe well with the H-2 system at altitude, but as he nears opening, he has difficulty getting enough O_2. He attributes this to depletion of his O_2 supply, and usually complains that the bottle was incompletely filled. In fact, when one activates an H-2 bottle at ground level, one must always work hard at inhalation since the aperture is so small that volume flow is inadequate to supply a normal tidal volume at ground level. However, at 30M' where this same flow expands to almost 4 times what it would be at ground level, the volume is sufficient to meet the demand. After exit the jumper is rapidly returning toward a sea level pressure condition. Therefore, even if flow through the aperture were to remain constant (which it does not[2]), his volume need would not be met at lower altitudes.

(b) When the pressure gauge on a gas cylinder is checked aloft, the gauge pressure frequently reads low and is interpreted to mean that the tank was incompletely filled. In fact, the cylinder was filled to specification pressure at ground level and ground temperature, but upon transport to temperature aloft, the pressure has fallen, often by a factor of 0.20 - 0.30 (for example, a tank filled to 2000 psi at 26°C will be at 1458 psi at -55°C).

(c) He must understand the problems of trapped gases and pressurized containers, so that he can effectively judge what can be carried safely in his pack and what must be left behind. Items known to be problems include:

1. Waterproof wrist watches.

2. Pressurized containers.

a. Shaving cream.

b. Insect repellent.

3. Fountain pens.

4. Contained liquids.

a. Medications.

b. Personal effects.

c. Canteens.

(2) Acceleration. Problems associated with acceleration should be discussed, especially the physiological complications of rotation about body axes.

(a) Epicyclic acceleration.

(b) Flat spins about a center of rotation, with:

1. Heart as the center of rotation.

2. Pelvis as the center of rotation.

b. Acoustics.

(1) He should be aware of the means available to him of ear protection against acoustic trauma, and be warned of the problems associated with the use of ear plugs during free fall.

(2) He should understand that upon landing, he can expect to have temporary hearing impairment because of:

(a) Exposure to the high noise levels in the aircraft which may produce a temporary threshold shift.

(b) The rapid recompression which may cause tympanic membrane damping with consequent obstructive type hearing loss.

c. General Physiology.

(1) Reaction times: The closing speed between an open canopy and a free falling jumper may be as much as 150 knots. He must be warned that following too closely above another jumper who may intentionally or unintentionally open his parachute may cause him to fall through the open canopy without even having time to respond. Examples of the delays imposed by perception and reaction time lags might include:

(a) It takes 0.400 seconds to achieve foveal perception after an extra-foveal appearance[3]. At a rate of descent of 250 feet per second the jumper would fall 100 ft before he even would <u>see</u> the opening canopy.

(b) It would take him an additional second and 250 feet of fall to achieve recognition of the opening parachute as a threat[3].

(c) It would take 0.500 seconds and 125 feet of fall for the parachutist to think about rip-cord pull, and to get his hand to the rip-cord handle[3].

(d) The sums of the times and distances mentioned suggests that it would require a <u>minimum</u> of 1.9 seconds and 475 feet between the time the opening parachute came into his field of vision, and the time he had his hand on the rip-cord handle.

(e) All of these are physiological delays. None covers the much longer delays involved in:

1. Pilot chute hesitation.

2. Non-specific delayed openings.

3. The 1.5 seconds or more necessary for line-stretch and beginning deceleration in all normal free-fall parachute openings.

It appears, therefore, that one should maintain no less than 850 feet of vertical separation between jumpers at an absolute minimum.

(f) It should be pointed out that as little as 14 feet of horizontal separation can prevent falling through a lower jumper's open canopy. A safety factor of 2 (i.e., 28 feet of horizontal separation when approaching another jumper from above) would seem advisable.

(g) He should also understand that it takes about 2.4 seconds to move his eyes from distant vision to his altimeter for a reading, and back to distant vision[4]. During this time he has fallen about 600 feet. This suggests that the jumper must look carefully for other jumpers around him each time before he checks his instruments, because he will be essentially blind to distant vision for the next 2.4 seconds after he begins an instrument check.

(h) In summary, rate of descent is deceptive, because there are no nearby stationary objects with which to relate. Those nearby objects the jumper can see are other jumpers, falling approximately as fast as he is himself. Therefore emphasis must be placed upon the speed of falling, closing times to stationary objects (i.e., an open canopy), the total inadequacy of the human sensorium to inform a jumper of the threat at hand, and the finite times required for perception and reaction.

(2) It should be explained that stereopsis is of no value to the free-fall parachutist in estimation of distances from the ground or closing speed with the ground at conventional opening altitudes. It is estimated by authorities in stereopsis that most people first begin to develop true stereopsis when angular disparity is between 20 and 24 seconds of arc. (The reported range in the literature is from 1.6 seconds to 24 seconds[5-9]). Geometric computation then indicates that with an interpupillary separation of 65mm (50th percentile for an adult male population[10]) stereopsis first begins when an object is 540-590 m (1772 ft - 1936 ft) from the observer. All objects beyond this distance from the observer appear to be in a single plane, and if any depth perception is possible, cues of other modalties than stereopsis are required.

(3) He should be familiar with some of the problems of night-vision and dark adaptation:

(a) Time required for full dark adaptation.

(b) The ease of destroying dark adaptation once it has developed.

(c) The advantages of peripheral vision over foveal vision under circumstances of poor illumination.

(d) The problems of judging distances and spatial relationships at night.

d. Respiratory Physiology. The jumper must have an understanding of the principles of respiratory mechanics and dynamics, and be acutely aware of the consequences of inadequate arterial O_2 content.

(1) He must be intimately acquainted with hypoxia, its symptoms, causes, consequences, and treatment. He should experience hypoxia himself, to:

(a) Introduce to him his own prodrome.

(b) Show him how unaware one can be of its onset.

(c) Convince him of its sudden and totally disabling effects.

(d) Assure him that he is susceptible.

(2) He should be aware of the concept of "time of useful consciousness" and be familiar with some representative times, e.g.,

20,000 ft	11 min.
25,000 ft	360 sec.
30,000 ft	115 sec.
35,000 ft	60 sec.
40,000 ft	35 sec.

He should know actions he can take to prolong his "time of useful consciousness" should he lose supplemental O_2.

(a) Avoid physical exertion.

(b) Maintain a slow shallow ventilation.

(c) At altitudes above 35,000 feet where time of useful consciousness is 60 seconds or less if one breathes ambient air normally, the period of useful consciousness can be greatly prolonged, to perhaps 2-3 minutes under the best of circumstances, by breath holding, since time of useful consciousness then depends only upon utilization of alveolar oxygen and is not compounded by wash-out of alveolar air and replacement by air with a much lower partial pressure of O_2.

(d) He should be trained in "buddy-breathing" so that should one jumper's regulator or bail-out bottle malfunction while aboard the aircraft he can be sustained by using a fellow jumper's O_2 until corrective action has been taken.

(3) He must be familiar with hyperventilation, its symptoms, causes, consequences, and treatment.

(4) He should be familiar with the sensations of positive pressure breathing and warned of some of its consequences.

(a) Hyperventilation.

(b) Fatigue of exhalatory muscles.

(c) Overdistention of the chest.

(d) Venous stasis.

e. Dysbarism.

(1) The anatomy and physiology of trapped gas spaces:

(a) Middle ear

(b) Paranasal sinuses

(c) Gut

should be described. He should understand not only how to clear these cavities and why clearing is necessary, but how to prevent difficulties, i.e.:

(a) Avoiding ingestion of carbonated beverages and gas producing foods just prior to the flight.

(b) Avoid clearing ears and sinuses with high O_2 containing gas upon descent.

(2) He should be familiar with the varied manifestations of evolved gas dysbarism.

(a) Creeps

(b) Bends

(c) Chokes

(d) Neurocirculatory collapses,

the steps which can be taken to prevent or delay their onset:

(a) Nitrogen wash-out,

(b) Diminished activity while at altitude,

and the measures necessary for effective self-aid and first-aid:

(a) Rest

(b) Immobilization of the affected part

(c) Rapid recompression

(d) 100% oxygen

(e) Treatment for shock is necessary.

He must be aware that evolved gas dysbarism can occur, not only at altitude, but also occasionally at ground level after a trip to altitude.

(3) He should know that "aerodontalgia" can occur.

f. Aviation Medicine.

(1) Thermal injuries, and combat ineffectiveness caused by thermal stress and the body's response to it.

(a) He must be thoroughly familiar with the concept of wind-chill, and the means available to protect himself against it.

(b) He must be aware of the possibility of heat cramps and/or heat shock should he exercise heavily while dressed for cold protection.

(2) He must be convinced of the deleterious effects of alcohol, tobacco, and drugs upon his judgment, reactions, and physical well-being at altitude.

(3) He should be trained in methods to prevent or minimize the possibility of motion sickness without use of medication. The following procedures have been suggested[11]:

(a) Ingestion of a light meal prior to the flight.

(b) Suppression of all head movement, and an absolute avoidance of coriolus inducing head movements[12].

(c) Maintenance of visual orientation outside the aircraft, and upon a distant object.

(d) Exposing the face to a flow of cool air.

(e) Loosening of constriction around the abdomen.

1. Belts.

2. Seat belts.

3. Reserve parachute belly band.

(f) Ingestion of warm liquids during flight.

1. Coffee.

2. Tea.

3. Bouillon.

When an individual notes onset of motion sickness, he should be isolated as much as possible from his fellow jumpers (to prevent contagion) and allowed to assume a supine position with the head position fixed, and eyes closed.

g. Equipment.

(1) Use and first echelon maintenance of oxygen equipment.

(a) Mask inspection and cleaning is especially important. By the very nature of parachuting and DZ's, the O_2 mask tends to collect debris, i.e., sand, leaves, pine needles, and hair, all which accumulate nicely in the exhalation valve. In addition the mask is commonly stuffed inside the helmet to protect it, and there can collect all manner of particles. The jumper, therefore, must be familiar with mask care and cleaning, and especially aware of the exhalation valve and the necessity to clean it before each jump.

(b) The jumper should be thoroughly familiar with the operation of:

1. The specific regulator(s) which he will be using.

2. The H-2 bailout bottle.

3. The walk-around bottle and its regulator.

4. Recharging the walk-around bottle from aircraft oxygen.

(2) Goggles tend to fog on the <u>inside</u>. He should know why this happens, how to prevent it, and what to do <u>should it</u> occur. He must be warned to avoid letting the condensate inside his goggles freeze, since once freezing occurs, he can then not clear the ice crystals without rewarming the goggles, and with the condensate frozen, he cannot see through the goggles.

(3) He must be taught how to adjust his O_2 mask to leak around the chin, and <u>not</u> around his nose. This further helps to prevent goggle fogging.

h. Survival. Although survival training cannot be considered "physiological", in fact, survival training generally devolves to the physiological training units. Emphasis should be placed upon survival training and especially upon two points:

(1) Water landings and survival after parachute landing in water.

(2) Use of the parachute, harness, and its associated gear in a survival situation, since this may be all the parachutist has with him should he be forced to leave the aircraft in an emergency situation.

OPERATIONAL RECOMMENDATIONS

In addition to the recommendations for training, the following operational recommendations are offered:

a. The personal and jumpmaster check of individual equipment performed on board the aircraft shortly prior to exit should be performed before the break in pressurization in order to reduce activity under the difficult conditions existing at altitude. This will reduce the possibility of hypoxia and evolved gas dysbarism.

b. Pressurization should be maintained as long as possible. By reducing the depressurized time at altitude, one reduces both the risk of hypoxia and evolved gas dysbarism, and in addition shortens the time during which interpersonal communication is difficult.

c. The ramp and doors should remain closed as long as possible. The jumper then is exposed to external temperature and wind-chilling for a minimum period.

d. Cold weather protective garb should be available to HALO parachutists which can be easily slipped on and/or off over ordinary field clothing, and without having to remove one's boots to do so. This will minimize the time that a jumper must be over-dressed before and after the jump, thereby reducing the possibility of heat injury and in addition greatly reduce the time of vulnerability after landing while clothes are being changed to conform with local ground conditions.

e. Studies in this laboratory have demonstrated that the heart is operating under a high workload during and immediately after free-fall even in the most experienced jumper[1]. As a part of the selection of parachutists for HALO training, some stress testing of the cardio-vascular system seems advisable.

f. Some type of reliable O_2 system is necessary in all aircraft from which HALO jumps may be made, to provide each jumper with a regulator and outlet. This may amount to as many as 40 O_2 outlets, in addition to the necessary crew outlets.

CONCLUSION

HALO (High Altitude, Low Opening) parachuting exposes the jumper to an unusual combination of environmental changes. The HALO parachutist must be trained to prevent combat ineffectiveness in himself and in his fellow jumpers caused by this rapidly changing hostile environment. It is important to emphasize that HALO is a delivery system and not an end in itself. In a real-mission situation, the jumper's job is just beginning when he touches down. He must land in a condition such that he can immediately proceed to fulfill his tactical mission. Training should be directed toward anticipation of hazards and prevention of ill-effects therefrom. Emphasis should be placed upon self-help and upon buddy aid, since the HALO parachuting situation requires self-reliance and individual initiative.

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OCTAVE BAND ANALYSIS OF INTERIOR NOISE IN A C-130 H AIRCRAFT

POS NO.	CONDITION	MR & S.D	OCTAVE BAND CENTER FREQUENCIES (IN HERTZ) C	31.5	63	125	250	500	1K	2K	4K	8K	16K
1	LEFT FRONT SEAT BEHIND PILOT WINDOWS AND DOORS CLOSED; DURING TAKEOFF	MR.	108.9	95 7	107.8	101.7	96 2	89 7	83.8	81.5	80.1	78.0	76.6
		S.D.	76	1.08	1.14	1.50	.94	94	1.07	1.05	.83	.66	.22
2	LEFT HAND SIDE AND LEFT HAND SEAT WINDOWS AND DOORS CLOSED; AFT SECTION, CRUISE	MR	100.3	95.7	96 1	90 2	92.4	88.1	75.9	69.3	68.3	69.5	74.3
		SD	.53	.84	.95	.52	.48	.55	1.08	.62	.66	.31	.06
3	RIGHT HAND SIDE AND RIGHT HAND SEAT WINDOWS AND DOORS CLOSED; AFT SECTION, CRUISE	MR.	100 2	95.8	95 9	89.9	93.2	88.1	76.7	69.9	69.2	69.3	74.2
		S.D.	.51	.80	.98	.52	.49	.50	.16	.43	0	.06	0
4	LEFT SIDE AT OPEN JUMP DOOR WINDOWS AND DOOR OPEN; CRUISE	MR.	108.0	102.7	104.0	99.4	99.6	97.8 —	96.2	93.6	91.4	89.3	82.0
		S.D.	.52	.80	.82	.47	.48	.49	.43	.44	.34	.13	.29
5	RIGHT SIDE AT OPEN JUMP DOOR WINDOWS AND DOORS OPEN; CRUISE	MR	108.0	102.0	103.3	100.2	99.7	98.6	96.7	94.3	92.1	90.7	82.2
		S.D	.53	.73	.85	.51	.40	.45	.08	.10	.33	.49	.38
6	LEFT SIDE OF RAMP WINDOWS AND DOORS OPEN; (WIND RUMBLING ON TAPE) CRUISE	MR	112.5	110.9	108 8	103.3	100.4	98.8	96.9	94.2	92.0	90.9	81.8
		S.D.	97	1.28	1.13	1.04	.80	.51	.33	.46	.27	.51	.16
7	RIGHT SIDE OF RAMP WINDOWS AND DOORS OPEN; AFT ON RAMP; CRUISE	MR.	110.0	106.0	105.7	102.2	100.7	99.4	97.0	94.1	91.7	90.4	81.75
		S.D.	.46	.76	.62	.52	.50	.26	.27	.20	.13	.50	0.0
8	WINDOWS AND DOORS OPEN; (WIND RUMBLING ON TAPE) MID RAMP; CRUISE	MR	117.0	115.9	113.5	108.4	104.8	101.4	100.3	96.7	95.3	92.7	86.3
		SD	.68	.83	.80	.82	.68	.55	.59	.63	.78	.68	72

APPENDIX I