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TECHNICAL BULLETIN

ALTITUDE ACCLIMATIZATION AND ILLNESS MANAGEMENT

HEADQUARTERS, DEPARTMENT OF THE ARMY

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MEDICAL 505*

HEADQUARTERS
DEPARTMENT OF THE ARMY
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ALTITUDE ACCLIMATIZATION AND ILLNESS MANAGEMENT

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*This bulletin supersedes TB MED 288, 15 October 1975.

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CHAPTER 1

INTRODUCTION

1–1. Definition and purpose

The subject matter of this bulletin is hypobaric hypoxia, an environmental stress resulting from ascent to progressively higher terrestrial elevation or altitude. This bulletin defines the threshold altitude at which hypobaric hypoxia becomes functionally and medically significant at 1,200 meters (m) (3,937 feet (ft)) above sea level. Throughout this bulletin, the terms altitude, elevation, hypobaric hypoxia, or hypoxia are considered interchangeable. This bulletin provides guidance to military and civilian health care providers, allied medical personnel, unit commanders and leaders to—

a. Develop an evidence-based prevention program to protect military personnel from altitude stress and associated adverse health effects.

b. Understand the physiologic responses and adaptations to altitude (chapter 2).

c. Implement procedures for managing altitude stress (chapter 3).

d. Understand the principles and proper use of altitude acclimatization tables (chapter 3).

e. Understand the physical work performance limitations caused by altitude (chapter 4).

f. Understand the neuropsychological performance limitations caused by altitude (chapter 5).

g. Understand the diagnosis and treatment of altitude illness and other medical conditions associated with altitude environments (chapter 6).

h. Identify the risk factors for altitude illnesses and implement prevention and treatment protocols (chapter 6).

i. Understand the principles and use of the altitude illness probabilities (chapter 6).

j. Prevent altitude injuries during training and operational deployments.

k. Provide background information for reporting and data collection of epidemiological information to note trends and to identify individual, work, and environmental factors that are not adequately controlled by preventive measures and policies.

1–2. References

Required and related publications are listed in appendix A.

1–3. Explanation of abbreviations and terms

The glossary contains a list of abbreviations and terms used in this publication.

1–4. Roles

a. Unit commander, leaders, and medical personnel, preventive medicine officers, medics and combat lifesavers, Soldiers, and local medical commands will coordinate to implement educational and training programs at all levels in the command based on the principles of this document. They should review all training and operations to make sure adequate planning is made for emergency medical support and altitude illness assessment and management where tactically feasible.

b. Unit commanders and leaders, when appropriate, will—

(1) Integrate the medical officer into all unit staff functions.

(2) Assess training/mission hazards from altitude exposure.

(3) Develop and implement controls for altitude exposure.

(4) Ensure Soldiers are provided adequate training, clothing, shelter, food, and beverages for altitude operations.

(5) Modify physical exertion levels to compensate for effects of increasing altitude.

(6) Ensure planning for all aspects of fluid and food availability.

(7) Modify altitude exposures to provide safe alternative training for individuals or units identified as being at particular risk for altitude casualties.

(8) Initiate a buddy system under altitude conditions and have Soldiers check each other for altitude illness.

(9) Ensure the study of terrain elevations at the deployment site in the advance planning stages, to include location(s) of the lowest elevations for possible altitude treatment activities, as well as the mean and highest elevations at the deployment site to assess impact on physical and cognitive work performances and susceptibility to altitude illness.

(10) Obtain regular real-time weather data and predictions to decrease the risk of cold or heat injury or to provide windows of opportunity for critical military operations.

c. Unit medical personnel or area support medical company staff will—

(1) Understand the commander's intent and mission goals, advise the commander on the potential adverse effects of altitude, and propose practical options for control of altitude exposure.

(2) Assess each component of altitude exposure (condition of the Soldier, elevation, duration of exposure, environmental factors, work load and mission requirements) to plan for the primary prevention of altitude illness by answering the following questions:

(a) What is the altitude and duration of altitude exposure?

(b) What is the altitude acclimatization status of the Soldier?

(c) What work intensity and duration are planned?

(d) Will the Soldier be with a buddy who can assist/watch over him or her to identify and mitigate development of altitude illness?

(3) Estimate the altitude acclimatization status of the unit and provide guidance for regulating physical activities according to the altitude and terrain in the deployment site.

(4) Assist the logistician in estimating water, food, clothing, and shelter requirements.

(5) Develop a casualty evacuation plan to include a means of monitoring patients.

(6) Educate the Soldiers about the steps needed to minimize the risk of altitude illness, to include hydration, nutrition, rest, and avoidance of risk factors (performing intense physical activity and ingesting alcohol and/or drugs or engaging in other forms of substance abuse).

(7) Educate Soldiers in recognizing the signs of impending altitude illness and the basics of buddy aid.

(8) Establish observational checks to detect effects of altitude exposure before illness occurs.

(9) Consider implementation of pharmacotherapy as necessary.

d. Preventive medicine officers will—

(1) Estimate the incidence of altitude illness and arrange required medical support associated with each course of action.

(2) Integrate the estimates of altitude illness incidence and severity, mission-compatible preventive measures and medical support requirements with the alternatives developed by the command staff.

(3) Become aware of what types of illnesses are being seen at sick call and what medications are being used.

(4) Interview Soldiers diagnosed with altitude illness to describe predisposing conditions and the circumstances surrounding the development.

(5) Use the Tri-Service Reportable Medical Events System to report altitude illness casualties.

(6) Communicate to field activities immediately upon recognition of altitude illness sentinel events and clusters.

e. Medics and combat lifesavers will support the prevention of altitude illness, recognize and treat altitude illness and implement measures to reduce the risk of additional illness.

f. Soldiers will—

(1) Be familiar with the causes of altitude illness and the risks of developing the illness.

(2) Know the practical measures they can take to prevent or ameliorate altitude illness.

(3) Become familiar with recognizing the early signs and symptoms of altitude illness.

(4) Use the buddy system to monitor performance and health.

(5) Report to the unit medic/medical officer as soon as possible if they or their buddy develops symptoms of altitude illness.

(6) Maintain adequate physical fitness to deal with the increased physiologic stress of altitude.

(7) Consume adequate food for optimal performance at altitude.

(8) Drink enough fluid to stay adequately hydrated.

(9) Ensure their deployment kits contain an initial supply of sunglasses, sunscreen, lip balm, and skin-care items for high ultraviolet exposure.

(10) Attend altitude illness threat and risk communication briefings and receive appropriate written altitude illness prevention materials well in advance of deployment.

g. Local medical commands will track altitude illnesses and injuries.

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CHAPTER 2

PHYSIOLOGIC RESPONSES AND ADAPTATIONS TO ALTITUDE

2–1. Altitude stress in military operations

a. Altitude is the vertical height above sea level of a land mass (for example, Mount Everest) or object (for example, aircraft). With increasing altitude, a decrease in the atmospheric barometric pressure causes a proportional decrease in the partial pressure of oxygen. Ultimately, with increasing altitude the oxygen partial pressure falls to a level at which there are measurable changes in physiological responses, physical and cognitive performance, and the emergence of altitude illness. Based on these measurements, functional definitions of altitude stress have been developed. In this bulletin, altitude stress is defined as terrestrial elevations at or above 1,200 m (3,937 ft). At and above this elevation, the decreased availability of oxygen (that is, hypoxia) in the atmospheric air causes functional impairments and altitude illness. Further demarcations of altitudes above 1,200 m (for example, moderate, high, very high and extreme altitudes) are provided later in this chapter. Throughout this bulletin, the terms altitude, elevation, hypobaric hypoxia, or hypoxia are considered interchangeable. Reference to altitude will be presented in meters, which is the measurement of altitude presented on U.S. military grid maps. Conversions between feet and meters is provided in the glossary.

b. Soldiers participating in military training and deployments do not often encounter altitude stress. Within the U.S., few military installations are located at altitude (table 2–1). Even at these installations, the area available for maneuvers may be very limited. For example, only the very limited mountainous regions of Fort Irwin are above 1,200 m. Thus, opportunities for training at altitude are limited. Nevertheless, the lack of familiarity and experience with strategies to cope with this unique environment should not be minimized because altitude exposure can deleteriously affect health, mental and physical performance, and morale. U.S. military deployments and operations at altitude have increased as a result of combat operations against military units or terrorist organizations based in high mountainous terrain. A list of countries with geographical elevations above 1,200 m is listed in appendix B. Units preparing for deployments to altitude regions should give strong consideration to scheduling training at altitude prior to deployment.

Table 2–1
Major U.S. military installations located at altitude within the U.S.

Military Installation	State	Altitude (m)
Fort Huachuca	AZ	1,432
USMC MWTC	CA	2,061–3,650
Fort Irwin, NTC[1]	CA	700–1,600
NAWS China Lake[1]	CA	640–2,700
Fort Carson	CO	1,780
Peterson AFB	CO	1,885
Air Force Academy	CO	2,031–2,620
Schriever AFB	CO	1,915
Cheyenne Mountain Air Force Station	CO	1,979
Buckley AFB	CO	1,655
Pohakuloa Training Area	HI	0–2,743
Cannon AFB	NM	1,285
Holloman AFB	NM	1,280
Kirtland AFB	NM	1,632
White Sands Missile Range	NM	1,190–2,000
Hawthorne Army Depot	NV	1,285-2,440
NAS Fallon	NV	1,220
Fort Bliss	TX	1,203
Dugway Proving Ground	UT	1,463
Hill AFB	UT	1,450
Tooele Army Depot	UT	1,500
F.E. Warren AFB	WY	1,876
Notes: [1]Indicates limited terrain above 1,200 m.		

Legend :
USMC=U.S. Marine Corps
MWTC=Mountain Warfare Training Center
NTC=National Training Center
NAWS=Naval Air Weapons Station
AFB=Air Force Base
NAS=Naval Air Station

c. U.S. military operations have been conducted successfully in altitude environments where Soldiers were required to endure the effects of hypoxia and push their physiologic limits (for example, Afghanistan). Nevertheless, the altitude environment can impair many aspects of normal military functioning in the field and, ultimately, the mission. These negative impairments can be minimized with training and experience.

(1) Operational problems often arise in altitude terrain. Mission requirements that demand sustained physical activity are most affected by altitude. Soldiers will fatigue sooner or must reduce their pace and/or lighten their load in order to accomplish many activities.

(2) Many Soldiers may develop altitude illnesses that can produce debilitating symptoms and require medical evacuation.

(3) In most Soldiers altitude induces symptoms, such as shortness of breath and rapid heart rate, that are unrelated to illness or injury. These symptoms can produce unwarranted concerns in Soldiers who are unfamiliar with this environment.

(4) Altitude terrain is frequently steep and rugged which increases the metabolic requirements for many activities, thus raising food and water requirements; yet supply can be difficult, resulting in inadequate nutrition and hydration.

(5) Altitude contributes to increased disease and non-battle injury since sick and injured Soldiers are susceptible to medical complications produced by hypoxia.

(6) Mission requirements that demand sustained physical activity increase the risk of developing altitude sickness.

(7) The steep and rugged terrain common to high elevations increases the risk of sustaining contusions and orthopedic injuries.

(8) Altitude contributes to impaired neuropsychological function and mood changes that may adversely affect the morale of the troops.

d. Military operations in remote altitude locations may have minimal logistical support so troops may find themselves under-equipped for the hostile environmental conditions. Soldiers in these situations must rely on their prior training and strong leadership in altitude acclimatization and illness management. This training can determine whether the mission will succeed or fail with mass casualties. Soldiers in these situations often are not fully prepared and consequently require unit commanders and trainers to actively plan to prevent altitude casualties. Military training exercises, whether initial entry training, special badge qualification training, or military operations training, should be conducted in altitude locations. This will provide an opportunity to teach personnel how to follow appropriate guidelines for successful completion of missions in the rugged terrain and while subject to hypoxia indigenous to the altitude environment.

e. Knowledgeable leadership is essential for training in altitude environments and for successful altitude military operations. Soldiers should have confidence that they can master the environment through the use of preventive measures or at least be cognizant of their limitations. Lessons learned from previous altitude deployments must be shared and emphasized. Leaders must learn their unit's capabilities and manage altitude exposure relative to the provided guidance. Guidance is based on the "average" Soldier, although there is significant individual variability. Supporting medical officers must ensure that the principles of this document are incorporated into the commander's plans and are applied to all phases of training and operations (pre, during, and post).

2–2. Altitude and hypoxemia

a. Decreased availability of oxygen in the atmospheric air (hypobaric hypoxia) is the only environmental stress unique to high terrestrial altitude. It lowers the oxygen supply to body tissues which causes altitude illness and a decline in physical and mental performance often seen in military and civilian personnel operating in high mountain terrain. Hypobaric hypoxia can also interact with other factors in the environment to increase the likelihood of environment-related injuries, or it can exacerbate preexisting medical conditions. Given its widespread effects, a basic understanding of hypobaric hypoxia is essential for medical personnel who support military units operating in high mountain regions.

b. There is a curvilinear reduction in the atmospheric barometric pressure (P_B) with increasing altitude (figure 2–1). In figure 2–1, the P_B is measured in millimeters mercury (mmHg). The exact magnitude of the reduction at any geographic location depends on the combination of elevation, latitude, weather, and season. Generally, within 30° latitude of the equator, the prevailing P_B is higher than predicted by the Standard Atmosphere Model, resulting in a "physiological altitude" that is generally 100–200 m lower than the actual terrestrial altitude. Conversely, the atmospheric prevailing P_B is lower than predicted by the Standard Atmosphere Model as one approaches the Poles (for example, South Pole elevation is 2,837 m, but atmospheric P_B is equivalent to 3,352 m). Table 2–2 shows the relationship between altitude and P_B based on the Standard Atmosphere Model (U.S. Standard Atmosphere 1962). To use the table to estimate altitude from a reported P_B in the U.S., use the "Station Pressure" observations from the National Oceanic and Atmospheric Administration (NOAA), usually reported in inches mercury (inHg). The U.S. Air Force (USAF) weather observations usually report P_B in millibars (mb), the North Atlantic Treaty Organization (NATO) Nations report in either mb or hectopascals (hPa), and medical units with arterial blood gas analyzers usually measure P_B in mmHg.

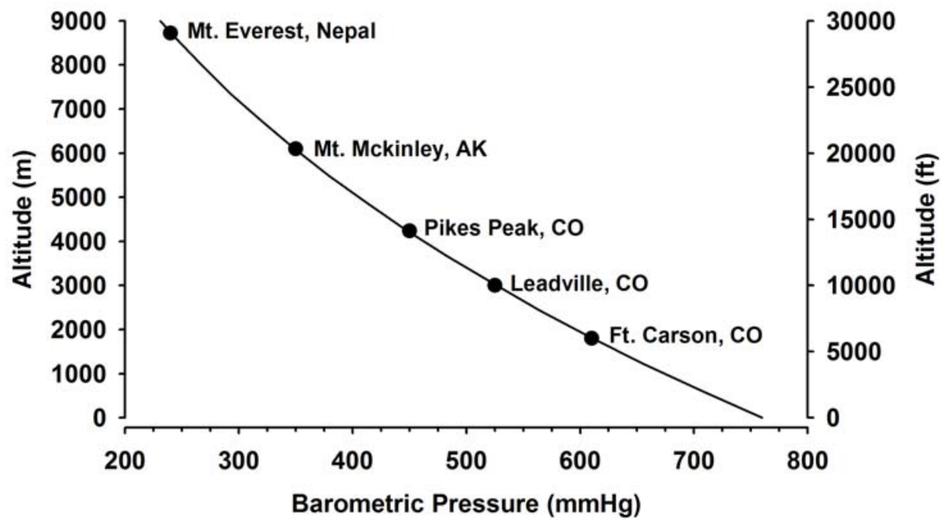

Figure 2–1. Relationship between barometric pressure and increasing altitude

Table 2–2
Relationship between altitude and barometric pressure based on the Standard Atmosphere Model[1]

Altitude (m)	Altitude (ft)	P_B (mmHg)	P_B (inHg)	P_B (mb)	P_B (hPa)
0	0	760	29.92	1013.25	101.32
500	1,641	717	28.23	955.90	95.59
1,000	3,281	674	26.53	898.57	89.86
1,500	4,922	635	25.00	846.58	84.66
2,000	6,562	596	23.46	794.59	79.46
2,500	8,203	561	22.09	747.92	74.79
3,000	9,843	526	20.71	701.26	70.13
3,500	11,484	494	19.45	658.60	65.86
4,000	13,123	462	18.19	615.94	61.59
4,500	14,765	433	17.05	577.27	57.73
5,000	16,405	405	15.94	539.94	53.99
5,500	18,046	380	14.96	506.61	50.66
6,000	19,685	354	13.94	471.95	47.20
6,500	21,327	331	13.03	441.29	44.13
7,000	22,966	308	12.13	410.62	41.06
7,500	24,608	288	11.34	383.96	38.40
8,000	26,247	267	10.51	355.96	35.60
8,500	27,889	249	9.80	331.97	33.20
9,000	29,528	231	9.09	307.97	30.80

Note:
[1]Adapted from U.S. Standard Atmosphere, 1962, U.S. Government Printing Office, Washington, DC, 1962.

c. While the percentage of oxygen (O_2) in one liter of air (that is, 21 percent (%)) does not change at altitude, the partial pressure of O_2 (PO_2) declines with increasing altitude according to Dalton's law of partial pressures ($PO_2 = P_B \times \%O_2$). For example, at sea level the P_B is approximately 760 mmHg, and the PO_2 in atmospheric air is about 160 mmHg (760 mmHg x 0.21). At 5,800 m, P_B is approximately 380 mmHg, and the PO_2 in atmospheric air is only 80 mmHg (380 mmHg x 0.21). As the inspired air passes through the respiratory passages, where it becomes totally saturated with water, the PO_2 is reduced by the partial pressure of water vapor (47 mmHg at body temperature 37 ºC). Thus, the PO_2 of moist-inspired gas is given by the expression $PIO_2 = ((P_B - 47 \text{ mmHg}) \times 0.21)$. The PO_2 of moist-inspired gas is further reduced in the alveolar air (PAO_2) because of incomplete replacement of alveolar air with atmospheric air, as well as the fact that O_2 is constantly diffusing out of the alveoli into pulmonary capillaries. The PO_2 on the arterial side of the capillary (PaO_2) is slightly less than the PO_2 of alveolar.