UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT DISTRIBUTION A:
AD-A194 595	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION USARIEM, Natick, MA — 6b. OFFICE SYMBOL (If applicable) SGRD-UE-MN	7a. NAME OF MONITORING ORGANIZATION
6c. ADDRESS (City, State, and ZIP Code) Natick, MA 01760-5007	7b. ADDRESS (City, State, and ZIP Code)
8a. NAME OF FUNDING/SPONSORING ORGANIZATION — 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and ZIP Code)	10. SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT ACCESSION NO
6.3A	3M263002D819	819AI	DA30522

11. TITLE (Include Security Classification) (U) Nutrient Requirements for High Stress Environments

12. PERSONAL AUTHOR(S) E.W. ASKEW, LTC, MS

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
MANUSCRIPT	FROM Ap 88 TO Ap 88	20 Ap 88	

16. SUPPLEMENTARY NOTATION

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	stress, environment, nutrient requirements

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

Certain types of stress can cause increased nutrient requirements to maintain physiological or psychological performance levels; however, not all stress elicits this response and relatively few nutrient requirements are actually increased. Environmental stress sometimes causes increased energy (particularly carbohydrate) requirement. Water requirements are often increased by heat, cold, and altitude exposure. Certain aspect of mental performance may be enhanced during environmental stress by dietary precursors of brain neurotransmitters such as tyrosine.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION UNCLASS
22a. NAME OF RESPONSIBLE INDIVIDUAL LTC ELDON W. ASKEW	22b. TELEPHONE (Include Area Code) 617-651-4874 — 22c. OFFICE SYMBOL SGRD-UE-MN

DD Form 1473, JUN 86 Previous editions are obsolete. SECURITY CLASSIFICATION OF THIS PAGE

UNCLASSIFIED

NUTRIENT REQUIREMENTS

FOR

HIGH STRESS ENVIRONMENTS

Prepared for:

R and D Associates Meeting

San Antonio, Texas

April 18-22, 1988

Eldon W. Askew, Ph.D.

LTC, Medical Service Corps

Military Nutrition Division

U.S. Army Research Institute of Environmental Medicine

Natick, MA 01760-5007

NUTRIENT REQUIREMENTS FOR HIGH STRESS ENVIRONMENTS

LTC Eldon W. Askew, Ph.D.

INTRODUCTION

The military battlefield has long been recognized as an arena of intense physical and mental stress (Figure 1). It is hard to imagine a more stressful environment than the battlefield of the immediate future. Combat will be intensive, rapid, violent, and fought day and night. Altered work-rest cycles, dramatic sleep loss associated with sustained operations and rapid deployment to unfamiliar environments very different from that to which the soldier is acclimated will impose high levels of stress. This will be exacerbated by the lack of adequate nutrition rising from interdicted supply lines, contaminated food or simply a lack of an opportunity to eat. These physical and emotional hardships of combat all contribute to the condition we loosely term "stress" (Figure 2). Stress is a rather ill-defined term. All of us have experienced it, yet few of us would agree upon its exact definition. Stress to one person might be merely stimulation to another. A generally accepted definition of stress is that provided by Dorland's Medical Dictionary (1):

> Stress is "The sum of all non-specific biological phenomena elicited by adverse external influences."

The enumeration of the contributors to stress and the general subject of stress itself are beyond the scope of this paper. For the purpose of this discussion, I would like to confine my remarks to the environmental stress that the soldier encounters in military operations (Figure 3) and discuss the special nutrient requirements arising from environmental stress. Finally, I would like to discuss the feasibility of providing specific nutrients to prevent stress related performance decrements.

NUTRIENT REQUIREMENTS

The familiar concept of the biological dose-response curve that has served us so well in other areas of medicine is also very applicable to illustrating essential nutrient requirements (2,3). Figure 4 depicts a dose-response curve for a hypothetical essential nutrient that is related to a physiological function. I would like to emphasize that such dose-response curves are representative of a population; an individual's dose-response curve may be broader or steeper, and possess a lower or higher optimal level than the mean function for a population. In general, however, it is possible to establish a range of nutrient intakes that will support a "normal" or, arguably, an "optimal" physiological function for the majority of individuals in a population. Controversy arises when the influence of "stress" is superimposed upon the dose-response curve. It is known that certain types of stress can result in an increased requirement for specific nutrients (4). The entire dose-response curve may be shifted toward the right requiring a higher nutrient intake to support a specific physiologic function (Figure 5). This is predictable when the stress causes an increased degradation and excretion of the nutrient itself (i.e. trauma and nitrogen) or an increased synthesis of products based upon that nutrient (i.e. lactation and calcium). Controversy arises when one generalizes that all types of stress automatically shift the dose-response curve to the right. The health food industry is quick to capitalize on such generalizations, ignoring the fact that, in many instances, a) the optimal nutrient intake range for many physiological functions is rather broad and b) the stress may not be severe enough to cause a perturbation in the body's equilibrium for a nutrient (5).

ENVIRONMENTAL STRESS AND ENERGY AND WATER REQUIREMENTS

I would like to illustrate how the dietary intake of two macronutrients, energy and water, can influence physical performance under the stress of an extreme or "hostile" environment. The relationship of energy and water requirements to environmental stress is illustrated in Figure 6. Heat, cold, and altitude can create increased requirements for water and energy while simultaneously decreasing the availability of these critical nutrients (6). Dehydration and caloric deficiency can severely limit physical performance (7). Fasting for as little as 24-27 hours can markedly reduce cycling or running endurance (8,9). Water deficits of as little as 2-3% of body weight can lead to performance decrements (10). Carried to an extreme, hypohydration can lead to reduced blood volume, decreased heat dissipation, reduced kidney function and ultimately death (11,12). Hyperhydration, on the other hand does not seem to provide any particular thermal advantage during exercise-heat stress but can delay the development of hypohydration (12).

The stress of work in hot or cold environments can increase energy requirements (6). The range of energy requirements for comparable workloads in temperate, cold and hot environments is shown in table 1.

(INSERT TABLE 1 HERE)

Consolazio (13) reviewed energy requirements of soldiers working in hot environments and concluded that there was approximately a 10% increase in metabolic rate for work at 100°F compared to work at 70°F. The increased energy requirement is thought to be due to the increased cardiovascular work needed to dissipate heat, increased sweat gland activity and elevated metabolic rate. Energy requirements for activities in the cold may also be increased by approximately 5-10% (6,14). This increase is more related to the biomechanical inefficiencies of walking on snow and ice and the hobbling effect of heavy clothing and boots than any direct effect on metabolism, provided adequate clothing is worn (15). If an individual exposed to the cold is inadequately clothed, shivering may cause a 5-fold elevation in resting energy expenditure (16).

There is little evidence that chronic high altitude exposure increases the requirement for any specific nutrients other than water and possibly iron (17). Altitude exposure causes an increased erythropoietic response as the oxygen delivery system of the blood attempts to compensate for reduced hemoglobin oxygen saturation (18). Normal dietary iron intakes are adequate to support the increased hemoglobin synthesis for males at high altitude; however the erythropoietic response in females benefits from iron supplementation (17). Water requirements at altitude can be greater than those at sea level due to the low humidity of the atmosphere at altitude and the hyperventilation associated with altitude exposure (17).

OTHER NUTRIENTS THAT MAY BE EFFECTIVE IN COMBATING ENVIRONMENTAL STRESS

Two other nutrients (carbohydrate and tyrosine) may be helpful in combating the stress of high altitude exposure. Consolazio et al (19) has demonstrated that high carbohydrate diets reduce the severity of the symptoms (headache, nausea, lethargy, mood) of acute high altitude exposure. Askew et al (20) suggested that carbohydrate supplementation may be beneficial in preventing physical performance decrements during the initial 48 hours of altitude exposure. Providing an additional 200 g of carbohydrate per day to soldiers working at altitude not only increased aerobic work capacity, but also prevented a negative nitrogen balance during the stressful first 24 hours of altitude exposure (20).

Banderet et al (21) have studied the combined effects of cold and altitude on performance, mood and symptoms normally associated with acute exposure to high altitude and cold. They found that tyrosine (100 mg/kg) decreased symptom intensities, adverse moods, and performance impairments caused by cold and high altitude exposure. Tyrosine is a neutral amino acid that is a precursor of three neurotransmitters; norepinephrine, dopamine and epinephrine. Some stressful situations cause depletion of these catecholaminergic neurotransmitters (22). Tyrosine may reverse stress-induced neurochemical deficits by providing additional precursor for the synthesis of these neurotransmitters (23). Neurotransmitters are critical messengers in the sequence of communication between neurons. Altering the synthesis, storage, neuronal levels, or release of neurotransmitters alters brain function and may be expected to affect behavior (24,25). Other neurotransmitters such as serotonin (tryptophan precursor) and acetylcholine (choline precursor) possess potential for dietary influence on the synthesis of brain neurotransmitters (26). These dietary precursors of neurotransmitters are shown in Table 2.

(INSERT TABLE 2 HERE)

SUMMARY

The challenge of providing nutrients for a high stress environment is providing a balanced palatable diet containing high levels of carbohydrate and energy. The best diet in the world will not be effective without adequate fluid replacement. Environmental stress increases energy and fluid requirements but, in general, does not result in increased vitamin and mineral requirements. However, certain nutrients such as carbohydrate and tyrosine may be useful in preventing some undesirable mood symptoms or performance decrements arising from stressful environments.

The opinions or assertions contained herein are the private views of the author and are not to be construed as official or as reflecting the views of the Department of Defense.

Table 1--Energy Requirements for Physical Activity in Temperate, Cold and Hot Environments[1]

Physical Activity	Environment Temperate	Cold (kcal/kg/body weight)	Hot
Light	32-44	35-46	40-54
Moderate	45-52	47-55	55-61
Heavy	53-63	56-68	62-75

[1]From Consolazio (13)

Table 2--Dietary Precursors of Neurotransmitters[1]

Precursor	Neurotransmitter(s)	Role of Neurotransmitter
Tyrosine	norepinephrine epinephrine dopamine	behavioral response to stress, mood, emotion, certain components of motor performance
Tryptophan	serotonin	regulation of sleep, pain sensitivity and mood state
Choline	acetylcholine	related to memory, social behavior, maintenance of mood

[1]From Growdon et al(24),Lieberman et al(25) and Wurtman (26)

FIGURE LEGENDS

Figure 1	Stress associated with the military battlefield.
Figure 2	Some contributors to physical and emotional stress.
Figure 3	Some contributors to environmental stress.
Figure 4	Schematic dose-response curve for nutrient requirements.
Figure 5	Schematic stress-induced shift of dose-response curve for nutrient requirements.
Figure 6	Effect of a "hostile" environment on work performance.

THE BATTLEFIELD

HEAT

COLD

MOUNTAINS

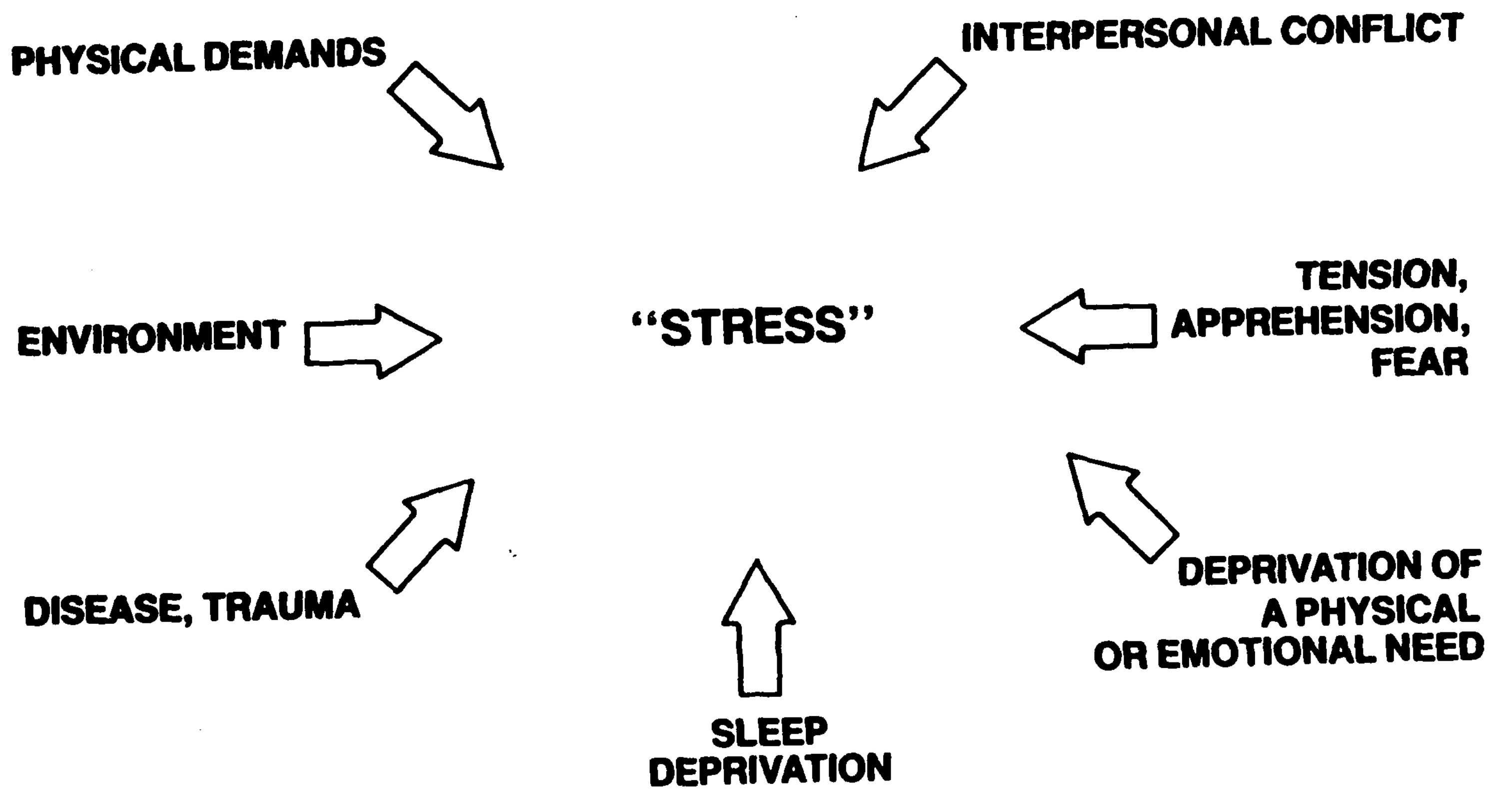
LACK OF FOOD, REST

DISEASE

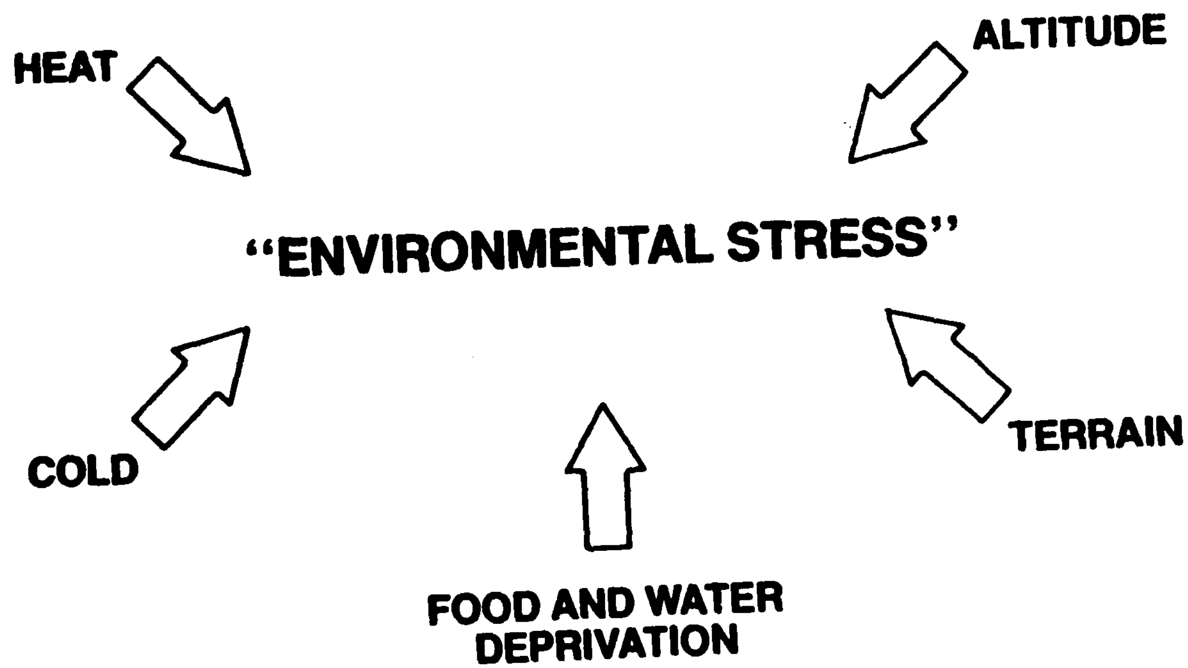
TRAUMA

FEAR

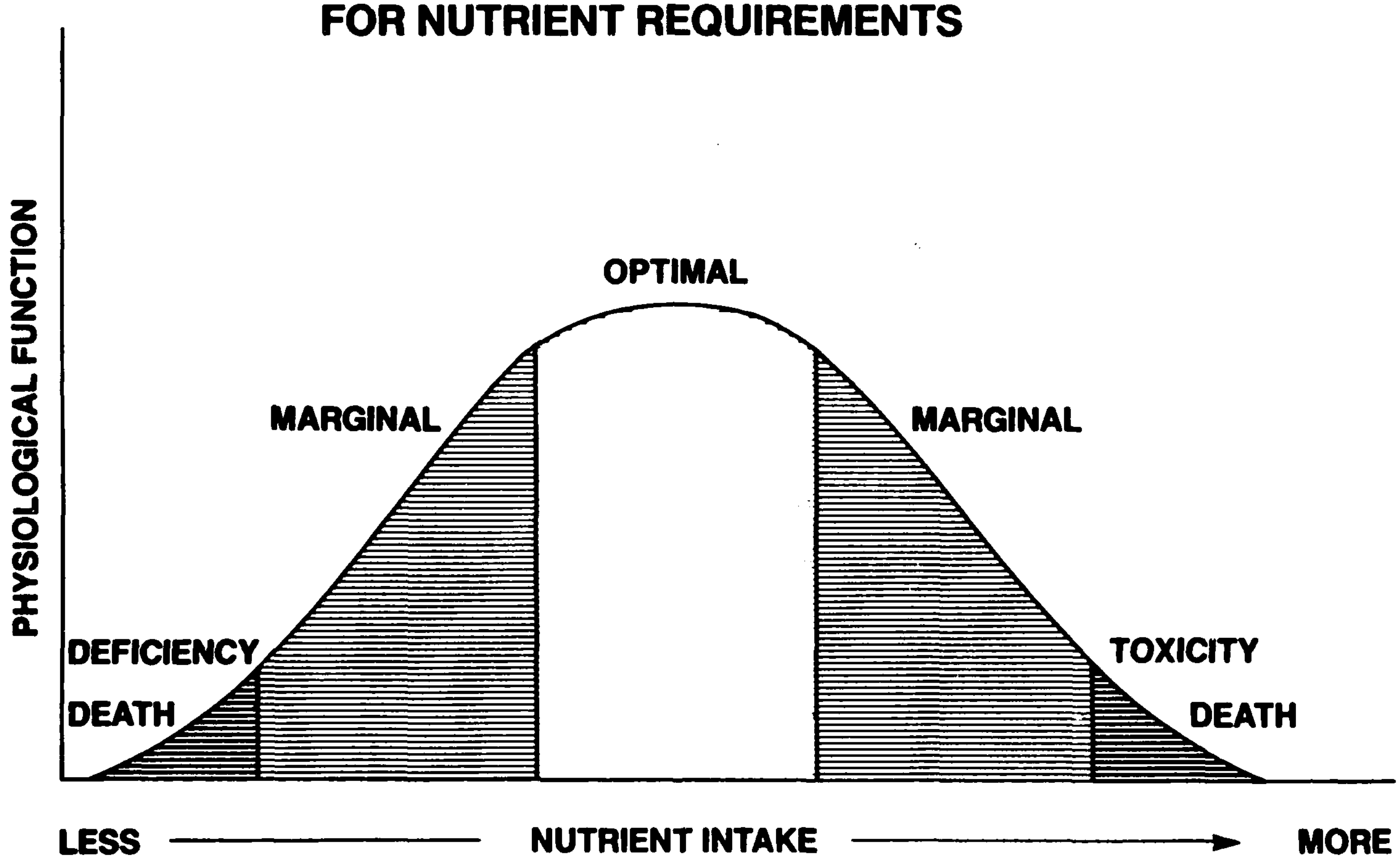
SOME CONTRIBUTORS TO PHYSICAL AND EMOTIONAL STRESS



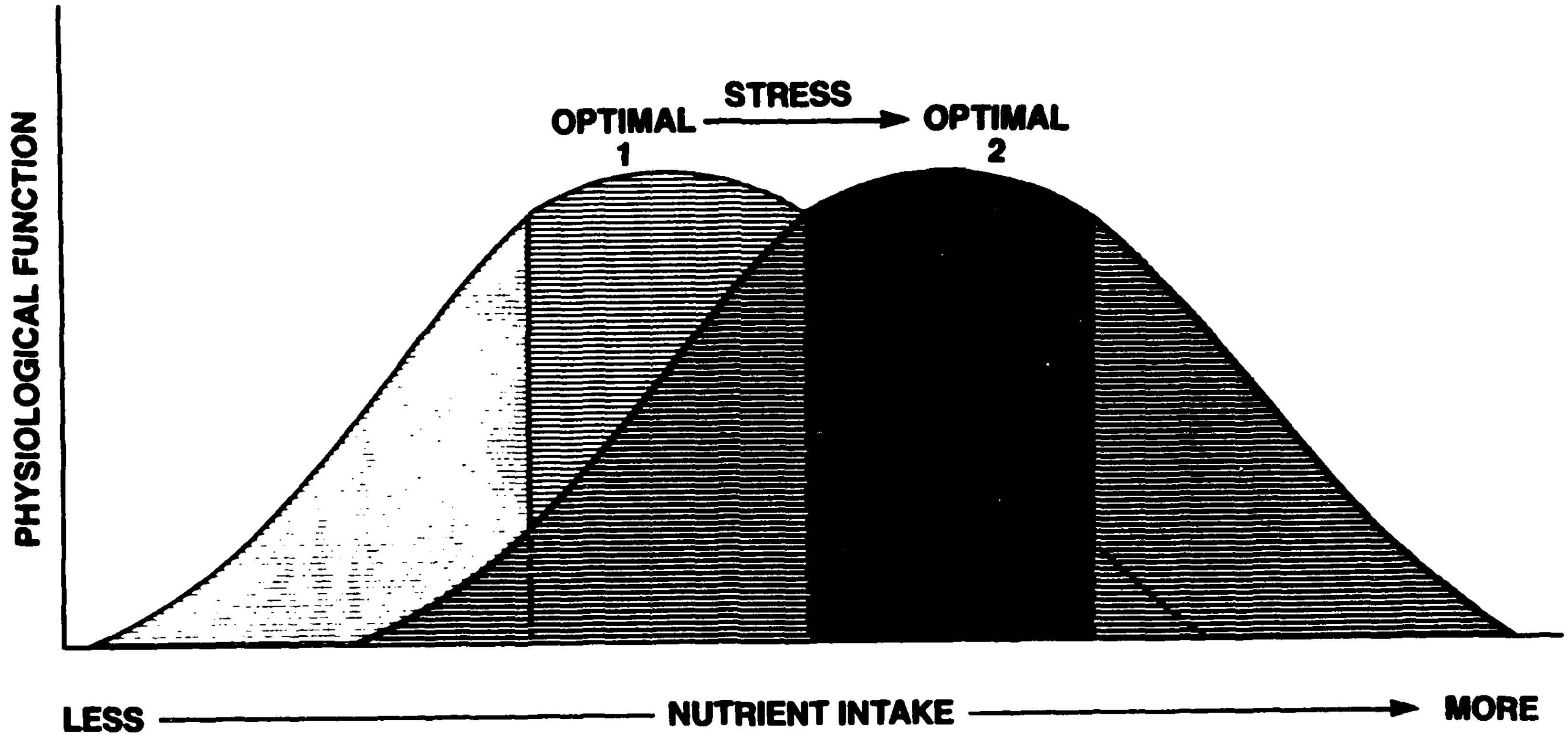
CONTRIBUTORS TO ENVIRONMENTAL STRESS



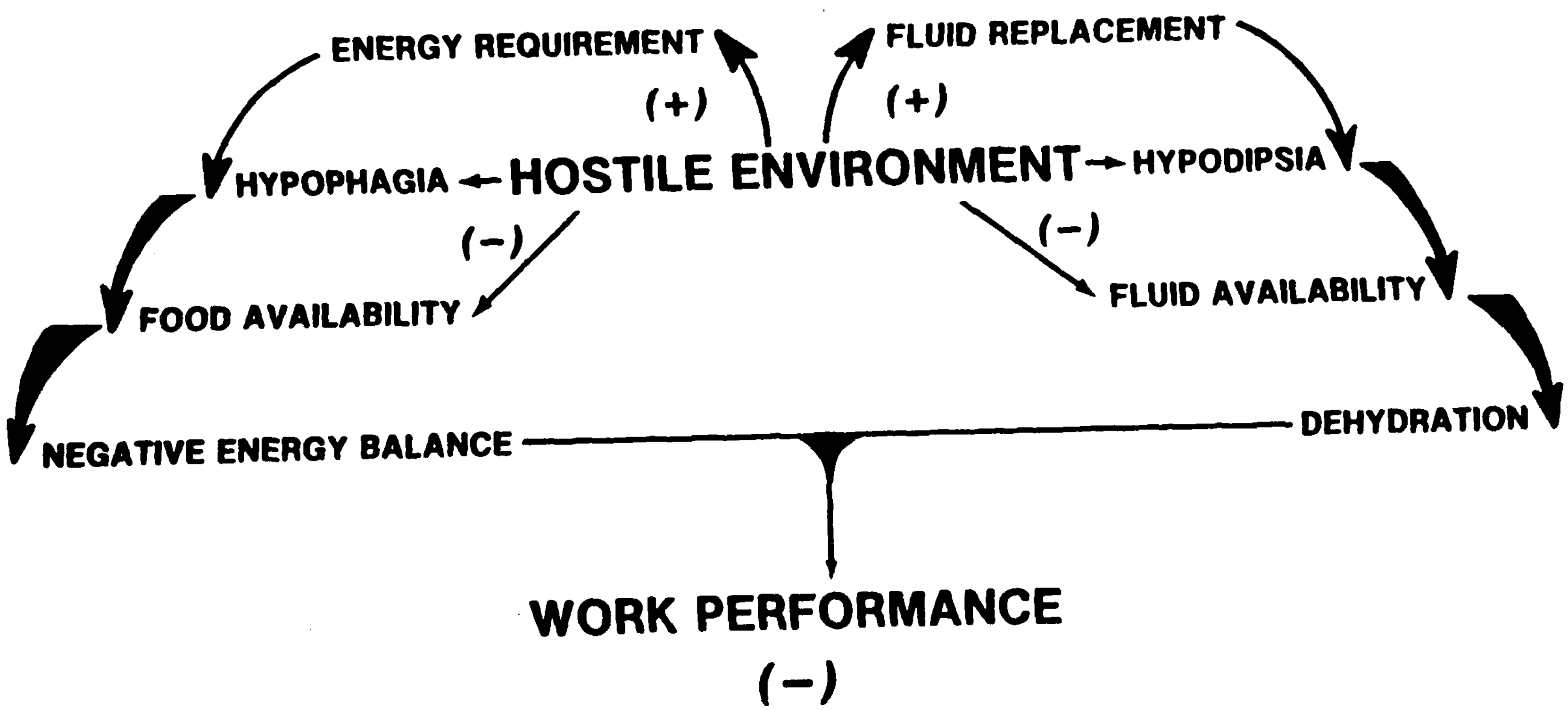
SCHEMATIC DOSE-RESPONSE CURVE FOR NUTRIENT REQUIREMENTS



SCHEMATIC STRESS-INDUCED SHIFT OF DOSE-RESPONSE CURVE FOR NUTRIENT REQUIREMENTS



EFFECT OF A HOSTILE ENVIRONMENT ON WORK PERFORMANCE



REFERENCES

1. ____________ Dorland's Illustrated Medical Dictionary, 24th Edition. W. B. Saunders Co., Philadelphia, PA. 1965.

2. Mertz, W. D. The significance of trace elements for Health. Nutrition Today, 18:26-31, 1983.

3. Mertz, W. D. The essential elements: nutritional aspects. Nutrition Today, 19:22-30, 1984.

4. Shils, M. E. and H. T. Randall. Diet and nutrition in the care of the surgical patient. In: <u>Modern Nutrition in Health and Disease</u>, 6th edition. Eds. R. S. Goodhart and M. E. Shils. Lea and Febiger, Philadelphia, PA. 1980, pp 1082-1124.

5. Marshall, C. W. Vitamins and minerals: help or harm? George F. Stickley Co., Philadelphia, PA. 1983, pp 1-5, 205-219.

6. Askew, E. W. Nutrition and performance under adverse environmental conditions. In: <u>Nutrition in Exercise and Sport</u>, Eds. J. Hickson and I. Wolinski. CRC Press, Boca Raton, FL. In Press, 1988

7. ____________ Workshop Summary. In: <u>Predicting Decrements in Military Performance Due to Inadequate Nutrition</u>. National Academy Press, Wash., D.C. 1984, pp 1-5.

8. Loy, S. F., R. K. Conlee, W. W. Winder, A. G. Nelson, D. A. Arnall and A. G. Fisher. Effects of 24-hour fast on cycling endurance time at two different intensities. J. Appl. Physiol. 61:654-659, 1986.

9. Nieman, D. C., K. A. Carlson, M. E. Brandstater, R. T. Naegele and J. W. Blankenship. Running endurance in 27-h-fasted humans. J. Appl. Physiol. 63:2502-2509, 1987.

10. Gisolfi, C. V. Impact of limited fluid intake on performance. In: <u>Predicting Decrements in Military Performance Due to Inadequate Nutrition</u>. National Academy Press, Wash., D.C. 1986, pp 17-28.

11. Hubbard, R. W., L. E. Armstrong, P. K. Evans and J. P. DeLuca. Long-term water and salt deficits - a military perspective. In: Predicting Decrements in Military Performance Due to Inadequate Nutrition National Academy Press, Wash., D.C., 1986, pp. 29-53.

12. Sawka, M. N., R. P. Francesconi and K. B. Pandolf. Circulatory and thermoregulatory actions of hydration during exercise - heat stress. In: Adaptive Physiology to Stressful Environments. Eds. S. Samueloff and M. K. Yousef. CRC Press, Boca Raton, FL, 1987, pp 85-90.

13. Consolazio, C. F. Nutrient requirements of troops in extreme environments. Army Research and Development Magazine, November 1966, pp 24-27.

14. Heroux, O. Nutrition in cold environments. In: CRC Handbook of Nutritional Requirements in a Functional Context. Volume II, Hematopoiesis, Metabolic Function and Resistance to Physical Stress. Ed. M. Rechcigl, Jr. CRC Press, Boca Raton, FL 1981, pp 523-542.

15. Buskirk, E. R. and J. Mendez. Nutrition, environment and work performance with special reference to altitude. Fed. Proceedings 26: 1760-1767, 1967.

16. Shepard, R. J. Adaptation to exercise in the cold. Sports Medicine 2:59-71, 1985.

17. Hannon, J. P. Nutrition at high altitude. In: Environmental Physiology: Aging, Heat, Altitude. Eds. S. M. Horvath and M. K. Yousef. Elsevier, Amsterdam 1980, pp 309-327.

18. Haymes, E. M. and C. L. Wells. Altitude and performance. In: Environment and Human Performance. Human Kinetics Publishers, Inc., Champaign, IL 1986, pp 69-91.

19. Consolazio, C. F., L. O. Matoush, H. L. Johnson, H. J. Krzywicki, T. A. Daws and G. J. Isaac. Effects of high-carbohydrate diets on performance and clinical symptomatology after rapid ascent to high altitude. Fed. Proc. 28:937-943, 1969.

20. Askew, E. W., J. R. Claybaugh, G. M. Hashiro, W.S. Stokes, A. Sato and S. A. Cucinell. Mauna Kea III: Metabolic effects of dietary carbohydrate supplementation during exercise at 4100 M altitude. U.S. Army Research Institute of Environmental Medicine, Natick, MA, Technical Report T12-87, May 1987.

21. Banderet, L. E., H. R. Lieberman, R. P. Francesconi, B. L. Shukitt, R. F. Goldman, D. D. Schnakenberg, T. M. Rauch, P. B. Rock and G. F. Meadors. Development of a paradigm to assess nutritive and biochemical substances in humans: A preliminary report on the effects of tyrosine upon altitude-and cold-induced stress responses. In: Biochemical Enhancement of Performance. Advisory Group for Aerospace Research and Development (AGARD) Conference Proceedings No. 415, 1987, pp 3-1 thru 3-10.

22. Stone, E. A. Stress and catecholamines. In: Catecholamines and Behavior. Ed. A. J. Friedhoff, Plenum Press, N.Y. 1975, pp 31-72.

23. Wurtman, R. J., R. Hefti and E. Melamed. Precursor control of neurotransmitter synthesis. Pharmacol. Rev. 32:315-335, 1981.

24. Growdon, J. H. and R. J. Wurtman. Dietary influences of neurotransmitters in the brain. Nutrition Reviews 37:129-136, 1979.

25. Lieberman, H. R., B. J. Spring and G. S. Garfield. The behavioral effects of food constituents: strategies used in studies of amino acids, protein, carbohydrate and caffeine. In: Diet and Behavior: A Multidisciplinary evaluation. Nutrition Reviews 44:61-69, 1986.

26. Wurtman, R. J. Ways that foods can affect the brain. In: Diet and Behavior: A Multidisciplinary Evaluation. Nutrition Reviews 44:2-5, 1986.