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Practical Reflections on Nutritional Intervention to Regulate Body Hormone Levels Under Survival Conditions in Extreme Environments

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Abstract: Extreme working conditions such as high-altitude hypoxia, polar cold temperatures, and limited field supplies continuously impose physiological stress on the human body, keeping it in a prolonged state of high metabolic pressure. These harsh environments disrupt the dynamic balance of the endocrine system, triggering hormonal imbalances, physical performance decline, and weakened immune function—key factors contributing to reduced environmental adaptability and diminished work efficiency among field personnel. Based on practical experience in frontline physiological support, traditional pharmaceutical protection methods and standard dietary models are often inadequate for the complex and variable demands of extreme field operations. This study takes three typical extreme environments—high-altitude hypoxia, polar cold, and energy scarcity in the field—as research contexts, integrating existing academic findings with real-world operational experience to analyze the underlying mechanisms by which these environments disturb hormonal homeostasis and to summarize nutrition-based interventions suitable for different field scenarios. Field practice has demonstrated that optimizing daily dietary structures and strategically supplementing functional nutrients can effectively alleviate stress-induced hormonal disturbances and maintain stable metabolic and endocrine function. Compared to pharmacological interventions, nutritional approaches offer greater safety, broader applicability across diverse settings, and the potential for long-term, routine implementation, better meeting the practical needs of field physiological support. This paper systematically categorizes targeted nutritional intervention strategies for various extreme environments, identifies current research gaps and shortcomings, and provides practical reference for enhancing physical fitness maintenance, health protection, and the optimization of field physiological support systems for outdoor workers.

Keywords: Extreme environment; nutritional intervention; hormonal readiness; Endocrine regulation; Survival adaptation.

1. Introduction

The remote mountainous areas, polar deserts, and uninhabited deserts, which are the locations for outdoor operations, have always been the key and challenging areas for ensuring the physical health of personnel. These areas have harsh natural environments and relatively weak logistical support and medical security resources. The overall guarantee conditions are far inferior to those in regular land-based operation scenarios. Multiple adverse conditions such as low pressure and oxygen deficiency, significant temperature differences between day and night, blocked material transportation, and enclosed operation spaces all continuously increase the physiological load on the human body, causing the body's metabolism to remain in an unstable fluctuating state. Whether it is short-term high-intensity outdoor surveys, engineering construction, emergency rescue tasks, or long-term regular duty, the stress regulation system of the human body is always in a high-load operation state, and the body hardly gets sufficient rest time. Stress injuries cannot be repaired in time [1].

Long-term exposure to extreme environments and repeated external stimuli will gradually disrupt the inherent secretion rhythm of human hormones, resulting in a series of physiological problems. Symptoms such as metabolic disorders, continuous decline in physical ability, weakened environmental stress resistance, and physical and mental fatigue and weakness are common physiological manifestations of outdoor workers. Hormones are the core substances that regulate human substance metabolism, immune defense, and environmental adaptation. The stability of hormone secretion is an important foundation for the normal operation of human organs and the smooth advancement of basic metabolism. From the actual observation of years of frontline support work, the problems of poor working condition and physical discomfort commonly experienced by outdoor workers are not only caused by excessive physical exertion, but also stem more from chronic physiological imbalance caused by long-term hormone disorder. This issue has received relatively low attention in previous outdoor support work and is also a weak link in the health management of outdoor personnel.

Drug intervention has been a common means for protecting the human body in extreme environments in the past. However, there are many limitations in practical application, and it is not suitable for long-term and regular outdoor personnel health protection. The conventional anti-stress drugs on the market have strict standards for storage temperature, transportation environment, and storage period. The simple and changeable environment in the wild is difficult to meet the storage requirements, and there is a high probability of drug efficacy decline and drug deterioration [2]. Long-term preventive use of anti-stress drugs will increase the metabolic burden on the human body and weaken the body's own immune regulation function. Short-term medication can slightly alleviate stress discomfort, but long-term reliance on medication will reduce the body's natural adaptation ability to extreme environments and cannot meet the needs of large-scale and long-term outdoor personnel health protection.

Nutritional intervention methods can effectively avoid the shortcomings of drug protection. With the advantages of

safety, non-invasive operation, wide applicability, and long-term implementation, they have become a high-quality way to repair physiological damage in extreme environments and stabilize endocrine status. Domestic and international scientific research experiments and population survey data can all confirm the positive effects of scientific dietary combination and targeted nutritional supplementation on improving stress hormone disorders and alleviating the decline in physical ability of outdoor workers. The current domestic outdoor nutritional support model is generally relatively loose, without formulating exclusive plans based on the physiological damage characteristics of different extreme environments, and the general dietary combination is insufficiently targeted and the adjustment effect is unstable, making it difficult to achieve large-scale implementation and promotion. This article, based on the actual pain points of outdoor support, combines existing research theories and on-site practical experience to summarize and organize a set of practical and implementable scenario-based nutritional intervention plans, helping to improve the outdoor physiological support system and enhance the survival adaptability of workers to extreme environments.

2. The Physiological Mechanism of Hormone Imbalance in The Body Under Extreme Conditions

The human endocrine system has an extremely high sensitivity to the environment and can quickly perceive subtle changes in the external environment and activate the self-regulation mechanism. Severe environmental fluctuations such as high-altitude low-pressure hypoxia, extreme cold in the polar regions, and long-term insufficient energy supply in the wild can exceed the conventional physiological regulatory thresholds, directly interfering with the synthesis, secretion, and metabolism of hormones, and completely disrupting the originally stable metabolic balance of the body [3].

Most of the physiological stimuli brought by extreme environments occur simultaneously and accumulate over time, continuously consuming the self-regulation ability of the endocrine system and disrupting the negative feedback balance mechanism of endocrine. This continuous damage accumulation will gradually induce systemic metabolic disorders. Combining long-term physiological monitoring data of personnel in the wild, it can be found that there are certain differences in the physical tolerance of different individuals. Long-term personnel stationed in extreme environments often have problems such as excessive activation of the stress system and abnormal secretion of related metabolic hormones. This is also the core physiological cause of frequent physical discomfort, continuous decline in physical fitness, and reduced work efficiency among frontline personnel.

Cortisol, as the core stress hormone in the human body, has the highest sensitivity to external environmental changes. When the human body is constantly exposed to extreme stress environments, the stress regulation system will remain activated, and the synthesis and release rate of cortisol will increase significantly, ultimately causing abnormal accumulation of cortisol in the body. Excessive cortisol will accelerate the breakdown metabolism of proteins and fats, and simultaneously inhibit the self-repair and growth process of body tissues.

If the body maintains this abnormal metabolic pattern for a long time, it will induce various irreversible chronic physiological damages, mainly manifested as loss of skeletal muscle, decline in body resistance, deterioration of anti-fatigue ability, and disruption of sleep rhythm. The existing data from field control experiments show that in extreme environments such as high-altitude and polar cold, the cortisol secretion level of the human body is 30% to 80% higher than that in the plain conventional environment [4]. The duration of extreme environmental exposure by personnel and the degree of hormone disorder are positively correlated. Long-term stress stimulation will reshape the basic hormone secretion pattern of the human body, causing persistent and difficult-to-recover endocrine imbalance.

Physical environment changes such as air pressure and temperature are important factors that induce hormone disorders. The metabolic stress caused by insufficient energy supply in the wild also interferes with endocrine homeostasis. This is often overlooked in field support work. When the duration of field operations is too long and the supply of materials is not timely, the body's energy intake cannot match the body's consumption, and it will actively activate the energy-saving protection mechanism. The body will reduce energy loss by lowering the secretion of thyroid hormones and the basal metabolic rate through this passive energy-saving regulation, in order to maintain stable basic vital signs.

This passive energy-saving regulation will directly lead to physical fatigue, slow response, and reduced exercise ability of the personnel. It not only affects the overall quality of daily field operations but also gradually weakens the body's tolerance to extreme environments, causing continuous physical functional deterioration.

The metabolic homeostasis of the human body is regulated by multiple hormones in coordination. A single hormone secretion imbalance will trigger a chain of physiological reactions, forming a vicious cycle. This physiological phenomenon is most typical in the hypoxic environment at high altitudes. The special environment of low-pressure hypoxia will cause abnormal elevation of some metabolic and appetite-related hormones, and the secretion level of the regulatory hormone for food intake is significantly suppressed. Most personnel working in the high-altitude environment will therefore experience reduced appetite, insufficient food intake, and a large energy intake gap. The state of metabolic imbalance will also continue to worsen.

The long-term follow-up data of personnel stationed in the highlands and conducting polar scientific research shows that people who are constantly in a high-consumption and low-supply state often have metabolic problems such as decreased insulin sensitivity and metabolic disorder. Continuous environmental stress will block the normal regulatory pathway of growth hormone, and the dual effects of energy deficiency and physical exhaustion will lead to a continuous lack of repair factors, a significant decline in the body's self-repair ability, and a significantly prolonged recovery period for minor stress injuries [5].

3. Practical Approaches for Regulating Hormones Through Nutritional Intervention in Different Extreme Environments

The stress causes, human metabolic response patterns, and physical injury manifestations in different extreme operation scenarios vary significantly. The types and degrees of

hormonal disorders also have distinct scene-specific characteristics. The general nutritional adjustment plans available on the market are rather general and can only meet the basic hunger-satisfying needs of the human body, failing to specifically address the specific hormonal disorders induced by different extreme environments. They cannot meet the refined health protection and physical maintenance requirements of personnel in the field. Scene-specific targeted nutritional adjustment can effectively stabilize the body's hormonal balance and enhance the body's tolerance to extreme environments. It is the core direction for the current refined development of physiological support in the field.

3.1. High-altitude hypoxic environment: Regulation of energy metabolism and hypoxic stress hormones

At altitudes above 3,000 meters, the plateau areas are the core operation sites for border defense duty, high-altitude engineering construction, and field geological surveys [6]. Hypoxia is the primary cause of hormonal disorders among personnel in this scenario. Prolonged exposure to low-pressure and hypoxic environments causes the human stress system to remain in an excited state, resulting in abnormal cortisol secretion, disordered appetite, and accelerated metabolic rate, among other physiological problems. As the duration of work accumulates, the physical fatigue of the staff continues to stack up, their physical strength gradually declines, their concentration and work efficiency significantly decrease. The endocrine imbalance problem of long-term stationed personnel will become more prominent.

In the past, the outdoor nutrition support work mostly focused on the bulk supply of high-calorie and carbohydrate foods, with the core purpose being to solve the problem of hunger among personnel. This single energy supplementation mode can only alleviate the superficial sense of hunger, but cannot repair the oxidative damage and hormonal disorders induced by hypoxia [7]. The actual physiological adjustment effect is very limited. By combining multiple field intervention control cases, it can be found that targeted supplementation of functional nutrients is an effective means to improve the hormonal state of high-altitude workers, reduce the physiological damage caused by hypoxia, and alleviate stubborn physiological problems such as chronic fatigue and abnormal metabolism caused by hormonal imbalance.

Magnesium and B vitamins can inhibit excessive stress responses in the body, reduce abnormal secretion of cortisol, and alleviate systemic oxidative stress damage. High-quality dietary protein can improve metabolic disorders induced by hypoxia, reduce muscle loss, and maintain the normal secretion rhythm of growth hormone and insulin. Selenium can effectively regulate the endocrine balance under hypoxic conditions, enhance the body's antioxidant capacity, and improve chronic fatigue, abnormal metabolism and other stubborn physiological problems caused by hormonal imbalance.

3.2. Low-temperature and severe cold environment: Stable thermogenic metabolism and stress hormones

The continuous low temperatures in polar and high-latitude cold regions will continuously activate the sympathetic nerve regulatory system of the human body, forcing the body to activate a compensatory metabolic mode. To maintain core body temperature stability and resist cold damage, the human body will actively increase the basal metabolic rate and exhibit typical stress responses such as elevated stress hormones and compensatory increases in thyroid hormones.

The physiological damage caused by high-altitude hypoxia is concealed. The consumption of the cold environment on the body's metabolism is more obvious. The body remains in a compensatory metabolic state for a long time, and the hormone regulatory system will continuously operate at an overloaded level, ultimately causing a disorder in the overall metabolic rhythm and continuous depletion of the body's cold tolerance and physical reserve [8].

Based on long-term practical experience in polar support, the core of nutritional regulation in a low-temperature environment does not lie in blindly increasing calorie intake. The focus is on stabilizing the body's heat production and metabolic rhythm, reducing the ineffective compensatory consumption of hormones, and ensuring the smooth operation of the endocrine system. Appropriate supplementation of complex carbohydrates and high-quality unsaturated fatty acids in daily diet can provide stable energy for the body to continuously generate heat, avoid abnormal breakdown of skeletal muscle proteins, and alleviate excessive compensatory secretion of stress hormones and thyroid hormones.

Functional nutrients such as vitamin C and linoleic acid can repair the damage to body cells and adrenal cortical cells caused by the cold environment, regulate the irregular hormone secretion pattern, and improve the problem of continuous decline in personnel's physical ability under severe cold conditions [9]. Multiple field measurement data can confirm that a scientifically balanced combination of nutrients can stabilize the hormone secretion ratio of the human body, retain the body's anabolic advantage, and significantly enhance the body's long-term adaptability to extreme cold environments.

3.3. Hunger and energy deficiency environment: Reversing the negative feedback regulation of hormones to restore homeostasis

Field operations are highly uncertain, with sudden situations such as extreme weather, equipment failures, and project delays causing disruptions to material supply, temporary food shortages, and depletion of supplies. Such scenarios are very common in field work, and the corresponding stress-induced injuries are often overlooked by the staff. A sudden interruption in energy supply directly disrupts the stable metabolic state of the human body, forcing the body to activate energy-saving protection mechanisms.

Long-term insufficient energy intake can inhibit the synthesis and release of thyroid hormones and body repair factors, disrupt the normal secretion rhythms of growth hormone and appetite-regulating hormones, and cause systemic hormonal imbalance within a short period of time, having long-term negative effects on the endocrine system [10].

In frontline support work, it can be clearly observed that most staff members will immediately consume a large amount of food for replenishment after the supply of materials is restored. This behavior has significant drawbacks. The hormone disorder induced by hunger stress has a long repair cycle and is difficult to manage. Intense supplementation in a

weak physical state not only cannot quickly restore the physiological state but also further increases the metabolic load of the body and damages the endocrine function.

Nutritional supplementation in scenarios of energy deficiency requires following the core principle of gradient recovery and gradual progress. Timely supplementation of basic composite energy substances can repair the disrupted appetite regulation pathway, improve the decline in appetite induced by hunger, and irregular eating, etc. Appropriate supplementation of complex amino acids can make up for the gap in repair factors in the body, optimize the regulation function of growth hormone, and help the body gradually rebuild metabolic homeostasis [11]. The long-term dynamic monitoring data of polar scientific expedition personnel fully prove that this gradient balanced supplementation mode can effectively repair the hormonal disorder caused by hunger stress and maintain the dual stability of the body's metabolism and endocrine system in the long term.

4. Practical Strategies for Optimizing Nutritional Intervention in Extreme Environments to Regulate Hormones

4.1. Establish a precise hierarchical intervention system

The intensity of stress in different extreme environments, the duration of personnel exposure to the environment, and individual physical fitness vary significantly. The types and degrees of hormonal disorders in workers also differ. A one-size-fits-all standardized nutritional support plan cannot adapt to the complex and variable scenarios of field operations. The intervention effects are uneven, and it is difficult to achieve precise physiological protection.

Based on practical experience in field operations and the characteristics of stress injuries, human stress in extreme environments can be classified into two types: acute high-intensity stress and chronic persistent stress. The injury mechanisms and focus of adjustment for these two types of stress are significantly different. Differentiated nutritional intervention plans need to be matched [12].

Acute high-intensity stress is more common in short-term high-intensity surveying, emergency construction, and emergency rescue scenarios. It requires stimulating rapid and high-intensity operations, and within a short period, it will cause intense fluctuations in hormones. The nutritional intervention focus for such scenarios lies in quickly replenishing energy and antioxidant nutrients to stabilize the basic hormone levels and avoid the occurrence of acute physiological damage.

Chronic persistent stress is concentrated in long-term high-altitude deployment, year-round polar scientific expeditions, and regular duty in uninhabited areas. The damage is cumulative, latent, and long-term, and it does not occur suddenly but continuously depletes the body's endocrine functions. For such scenarios, there is no need for high-intensity specialized nutritional supplementation. A long-term balanced diet combination and continuous supplementation of trace nutrients can gradually regulate hormone secretion rhythms and delay the development of chronic metabolic disorders. Field support work can be adjusted in combination with operation intensity, duration of deployment, and real-time physiological data of personnel, establishing a stratified and personalized precise nutritional support model [13].

4.2. Optimize the ratio and supply mode of nutrients

The traditional on-site nutrition support model is generally rather simplistic, with the focus mainly on providing basic calorie supply. The dietary structure is monotonous and the nutritional ratio is simple, which can only solve the problem of people's hunger but neglects the core needs of physical function regulation and endocrine homeostasis maintenance. This model does not carry out special regulation for the hormone disorder problem in extreme environments and cannot meet the refined requirements for the stable operation of the endocrine system.

The core of scientific nutrition intervention is to rely on the synergistic regulatory effect of macronutrients and micronutrients to comprehensively improve abnormal stress metabolism and regularize the disordered hormone secretion rhythm. Carbohydrates, proteins, fats and other macronutrients are the basic carriers for hormone synthesis and body substance metabolism, which can provide sufficient energy for the body's basic operation and ensure the orderly progress of the metabolic process.

The daily intake doses of micronutrients such as magnesium, selenium, B vitamins and unsaturated fatty acids are relatively small, but they play an indispensable role in endocrine regulation and can effectively alleviate excessive stress in the body, enhance antioxidant capacity, and improve the problem of abnormal hormone secretion rhythm during the day and night. The conditions for storing, transporting, carrying and supplying on-site materials are limited, and a single supply mode is difficult to simultaneously meet the dual needs of basic energy supply and stress protection [14].

Based on practical experience on the front line, the "daily basic supply + specialized strengthening for high-intensity operations" composite support model is more in line with the complex working conditions in the field. Daily reliance on balanced diet to maintain the stability of basic metabolism, targeted strengthening of functional nutrient supplementation during high-intensity operations and extreme weather periods can effectively improve the scene adaptability and actual conditioning effect of nutrition intervention.

4.3. Establish a mechanism for monitoring and intervening in hormone levels

Hormone indicators serve as the core data support for quantifying extreme environmental physiological damage, evaluating the effectiveness of nutritional interventions, and optimizing the guarantee plan. For a long time, most of the outdoor nutritional guarantee work has been carried out based on the practical experience of the staff, lacking precise data support. The guarantee plans are highly homogeneous, with obvious shortcomings in targeting and precision. Most nutritional adjustment work is somewhat.

The improvement of the quality of outdoor physiological guarantee requires breaking away from the traditional empirical working mode and establishing a systematic hormone dynamic monitoring system to promote the transformation of guarantee work towards dataization and precision. Staff can regularly test core endocrine indicators such as cortisol, thyroid hormones, leptin, and insulin, accurately identify the specific types and severity of personnel's hormone imbalance, and locate the core problems of physical physiological damage [15].

Guarantee personnel can rely on the real-time updated monitoring data to flexibly adjust the dietary combination, the dosage of nutrients supplementation, and the frequency of supply, avoiding ineffective supplementation, excessive supplementation, etc. , and build a complete work loop of "monitoring and evaluation - targeted adjustment - review and optimization", improving the scientificity and practicality of outdoor nutritional guarantee, and making the nutritional intervention plan fully meet the actual physiological needs of the workers.

5. Current Issues and Research Prospects

Based on the existing academic research results and the current situation of field operations, the research system in the field of extreme environment nutrition regulation in China still has significant shortcomings. The overall research depth and practical application value need to be further explored. Currently, most studies focus on the independent regulatory effects of a single scenario and a single nutrient, with the research focus leaning towards basic mechanism analysis. Topics such as multi-nutrient collaborative intervention, cross-adaptation in multiple scenarios, and long-term maintenance of hormone homeostasis, which have strong practical value, have relatively scarce relevant research results. There is no standardized nutrition intervention system that can be scaled up and adapted for field operations within the industry. A large number of theoretical research results cannot be transformed into practical safeguard measures.

Objective factors such as limited field test conditions and strict on-site safety control standards have greatly restricted the advancement of research in this field. Most current research conclusions are based on animal experiments and short-term observational data of small sample populations. There is a serious lack of large-sample, long-term follow-up control studies for frontline field workers. Key issues such as the actual regulatory efficacy of nutrients on human hormones, the optimal supplementation dose, and the long-term intervention safety still need to be supported and improved with a large amount of field measurement data.

The lack of specialized field testing equipment is also a key bottleneck for industry development. Currently, there is a shortage of portable, low-cost, and efficient rapid hormone detection equipment, which cannot achieve dynamic tracking of personnel's endocrine status, limiting the implementation of refined and personalized nutrition guarantee models [16].

Combining the research shortcomings and practical pain points in this field, it is possible to iterate and upgrade from the three dimensions of research, application, and technology. Academia can conduct multi-scenario, large-sample, and long-term tracking human control trials to explore the dynamic evolution laws of hormone disorders in extreme environments and the core mechanisms of nutrition regulation, and build a standardized and scenario-specific specialized nutrition intervention system.

At the industry application level, it is possible to integrate multi-dimensional information such as environmental parameters, individual constitution, work intensity, and hormone monitoring data to build an intelligent nutrition intervention model, achieving pre-judgment and targeted correction of abnormal hormones. At the technical level, it is necessary to meet the actual needs of field storage, carrying, and consumption, and develop specialized extreme environment nutrition products that are resistant to storage, portable, and highly adaptable, to enhance the practicality of on-site intervention [17]. The deep integration of theoretical research and field practice can continuously improve the extreme environment human nutrition guarantee system and enhance the adaptability of operation personnel to extreme environments.

6. Conclusion

This paper takes three typical extreme environments - high-altitude hypoxia, polar low temperatures, and energy scarcity in the field - as the research carriers, analyzing the differentiated impacts of different extreme scenarios on human hormone secretion and metabolic homeostasis, summarizing the formation characteristics and evolution patterns of endocrine disorders in various environments, and combining field practical experience, constructing a scenario-based and targeted nutritional intervention implementation path.

This study confirms that traditional drug protection methods with limited scenarios and potential safety hazards are not suitable for long-term and regular protection in the field. The nutritional intervention model of dietary structure optimization and functional nutrient supplementation can effectively improve physiological problems such as abnormal hormones, metabolic disorders, and appetite disorders induced by extreme stress, stabilize the endocrine homeostasis of the human body, and delay physical decline, and is suitable for long-term and regular physiological support in the field.

The layered nutritional intervention plan constructed in this study is in line with field practical conditions and can provide reliable practical references for the health protection and physical maintenance of frontline personnel. This study has certain limitations. The research focuses on the regulation analysis of a single scenario and a single nutrient, and the depth of systematic research on multi-nutrient collaborative intervention and cross-adaptation of multiple scenarios is insufficient. The research data mainly relies on existing literature and small sample trials, and there is a lack of large-scale field measurement data. The absence of rapid detection equipment in the field also hinders the implementation of the refined nutritional support model.

Future research can focus on promoting large-sample, long-term follow-up field control trials, improving the mechanism of multi-nutrient combined regulation, building a standardized and scenario-based field nutritional support system. Develop portable supply products and rapid detection equipment that meet field practical needs, build an intelligent intervention model, continuously optimize the nutritional regulation system for human stress in extreme environments, and further improve the scientific and precise level of field physiological support work.

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