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**Session JP1
Room 1
2:30 - 5:30 p.m.**

**Medical, Psychophysiological, and
Human Performance Problems During
Extended EVA**

NEW DEVELOPMENTS IN THE ASSESMENT OF THE RISK OF DECOMPRESSION SICKNESS IN NULL GRAVITY DURING EXTRAVEHICULAR ACTIVITY

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INTRODUCTION

It has been noted that the risk of decompression sickness (DCS) during extravehicular activity (EVA) is less than would be expected from ground-based experiments testing the oxygen prebreathe protocols. We have conducted a series of experiments over the past several years to examine the hypothesis of lower body adynamia (as would be encountered in 0-g) as a mitigating condition in DCS formation. This would be a result of the reduction in formation of tissue gas micronuclei that are the "seeds" which grow into pain-causing bubbles during decompression.

METHODS

Test subjects have been exposed to reductions of pressure in an altitude chamber in both the seated and standing posture. In some cases, subjects performed oxygen prebreathe before the altitude expose; in some subjects, mild arm and leg exercise was performed).

RESULTS

Data indicates that the reduction in gas bubble production and decompression sickness is significantly reduced (approximately by an order of magnitude) in the seated (adynamic) subjects. These experiments further indicated that tissue micronuclei have lifetimes on the order of several hours, not weeks or months as previously thought. We now have data from other laboratories both in the United States and Europe that corroborate our original NASA hypothesis. This concept of mild exercise during prebreathe in adynamic subjects is now being further explored to develop oxygen prebreathe schedules of one to two hours duration.

DISCUSSION

This work is being combined with examinations of the DCS/prebreathe algorithms to develop schedules that combine the time course and intensity of musculoskeletal activity and inert gas washout with oxygen.

THE DYNAMIC OF PHYSIOLOGICAL REACTIONS OF COSMONAUTS UNDER THE INFLUENCE OF REPEATED EVA WORKOUTS: THE RUSSIAN EXPERIENCE.

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INTRODUCTION

Extravehicular activities continue to be one of the most dangerous and emotionally stressful operations of cosmic flight. This situation is primarily due to a lack of individual and cumulative experience regarding arduous mechanical (physical) work in microgravity conditions. In addition, the space suit is the final technical barrier and the only protective countermeasure against the deep vacuum of space. The visual information received by individuals during EVA regarding the infinity of space appears to enhance an emotional state similar to the typically observed "altitude fear." Together with the unusual microclimate of the space suit, the specific gas environment and the principles of thermoregulation of the suit system result in pronounced physiological reactions by many bodily systems.

RESULTS AND CONCLUSIONS

The accumulation of individual experience during on-ground training in vacuum chambers, in modeled microgravity, and in actual EVA have enabled the normalization of physiological reactions, increased work capacity effectiveness, and simultaneously decreased the metabolic cost for cosmonauts engaged in EVA. The opinion of the cosmonauts is that the most advisable regime of repeated workouts is at 4-7 day intervals. In emergency situations, it is possible to carry out EVA with a 2-3 day interval. There is a significant amount of important scientific and practical information that can be gained by analyzing physiological reactions during EVA. Therefore, it is highly advisable to develop standardized methods for monitoring the status of the cosmonaut during EVA based on the cumulative experience of Russian and American specialists from on-ground training and actual EVA.

MEDICAL EMERGENCIES IN SPACE

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INTRODUCTION

Predicting and ranking the probability of occurrence of medical contingencies (e.g., illness or injury) during space missions is difficult, in part because the database is too small to allow definitive conclusions. Moreover, medical risk assessments derived from surrogate populations will be imprecise, and the associated magnitude of error is nearly impossible to estimate accurately. Attempts by physicians and epidemiologists to analyze the results collected to date and use those analyses to generate risk "scores" are an overextension of data sources and should be viewed skeptically.

DISCUSSION

Another approach to assessing medical emergencies in space is to focus on the adequacy of in-flight medical care and the ability to return crews safely. NASA's efforts to design a Health Maintenance Clinic for space are well underway. Many of the technologies to be used in this Clinic have been identified, and competing technologies are being evaluated. Many established technologies used routinely on Earth cannot be adapted readily to the space flight environment, particularly those used in imaging and in clinical laboratory equipment. Emergency scenarios generated from space flight experience and risk assessments have been developed and studied. These and other scenarios will be helpful in determining how well Earth-based diagnosis and treatment paradigms can be applied in combination with the clinical resources planned for space.

THE EVOLUTION FROM 'PHYSIOLOGICAL ADEQUACY' TO 'PHYSIOLOGICAL TUNING.'

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The challenge of the first wave of space exploration was the sustenance of life in the face of the unforgiving circumstances of extraterrestrial conditions. The prime imperative was the support of the astronaut in terms of providing short-term, micro-environments that permitted undisturbed physiological functioning. It was assumed that where conditions were physiologically tolerable, astronaut performance would remain unimpaired. This concept of physiological adequacy, although demonstrably flawed, served as an unacknowledged design foundation. At the turn of the century, we are in the beginning stages of the second wave of space exploration including the planning of long-term planetary missions and extended residence in space. Today, the imperatives are the uses of space and in particular the unique human role in space development. Consequently, our design strategy has to turn from physiological support to physiological tuning. By this we mean the use of knowledge of physiological systems to subserve and promote optimal performance capability. Given the cost of the sustenance of human residence in space, it is no longer sufficient to simply ensure tolerable conditions. Rather, using NASA's human-centered design innovations, we seek to promote increases in performance efficiency and particularly the reduction of human error in an error intolerant environment. The underlying model which permits the linkage between physiological response patterns and performance efficiency is an extended-U innovation which draws direct parallels between success and failure in physiological and psychological functioning. How performance error may be reduced and performance efficiency increased using the tenets of this approach will be adumbrated.

FIVE ZONES OF SYMMETRICAL AND ASYMMETRICAL CONFLICTING TEMPERATURES ON THE HUMAN BODY: PHYSIOLOGICAL CONSEQUENCES

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INTRODUCTION

This investigation assessed conflicting temperatures on the body surface to evaluate how signals from differing receptor fields determine total body heat status, and the nature of the processes in the thermoregulatory center that manage the stabilization of heat balance. The aim of this program of research is to provide better information on how to manage and protect the body when conflicting temperatures occur during EVA, diving, or in other extreme activities.

METHOD

A cooling/warming suit was constructed with five different zones on each side of the body for cooling and warming the body surface. The suit is divided sagittally so the same five focal areas on the left and right halves of the body can receive the same (symmetrical) or differing (asymmetrical) thermal input, depending on the particular experimental condition. The input of simultaneous warming and cooling to different focal zones results in a body mosaic of conflicting temperatures on the legs, feet, hands, torso and arm, and head. Physiological status was evaluated by electrocardiogram, blood pressure, and thermoregulatory assessment (inlet and outlet heat evaluation, surface and core temperature monitoring, rate of sweating).

RESULTS AND CONCLUSIONS

Comparison of physiological reactions to different sizes and different regimes of warming/cooling panels distributed on the body surface indicated the following: 1. the greater the number of panels with conflicting temperatures on the surface, the more difficult it is for the thermoregulatory center to recognize the existing heat content and heat balance and undertake protective reactions; 2. sweat distribution manifests a mosaic topography that follows the temperature redistribution; 3. sagittally symmetrical and nonsymmetrical distributions of cold and warm panels have a significantly different influence on thermoregulation; 4. it is difficult for subjects to discriminate conflicting temperatures on the surface of the head.

HUMAN PERFORMANCE AND SUBJECTIVE PERCEPTION IN NONUNIFORM THERMAL CONDITIONS

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INTRODUCTION

Marked changes in the microclimate within the space suit may occur during extended duration EVA as a result of physical exertion and differential exposure of different parts of the body to thermal extremes. Nonuniform thermal conditions within the space suit effect overall physiological status; these conditions may also have a significant effect on work performance during EVA. Greater knowledge about the nature of changes in work performance and subjective state has direct relevance to more accurately monitoring the safety of the astronaut and enhancing task effectiveness.

METHOD

Four male and four female volunteers were each evaluated in eight different protocols of nonuniform thermal conditions. The experimental paradigm involved the development and use of a sagittally divided heating/cooling tube suit enabling differential variation of temperature on each side of the body. Core and skin temperature were continuously monitored on numerous sites of the body. A vigilance task was used to measure reaction time and other attentional parameters at periodic intervals across each session. Subjective ratings were obtained of perceptions of heat and cold on the left and right sides of the body and the body as a whole. Overall perception of alertness, tension, and psychological comfort were also measured.

RESULTS

Marked individual differences were demonstrated across subjects in response to nonuniform thermal conditions. Several subjects showed no change in reaction time irrespective of the particular differential temperature condition they were experiencing. However, other subjects exhibited decrements in reaction time with the experience of significant heating on one side of the body. Cold on one side of the body had a greater influence on ratings of overall thermal state than did heat. Some subjects had difficulty discriminating between differential cold temperatures on the two sides of the body when one side of the body was significantly cooled in comparison to the other side. Shifts in the direction of extreme cold were associated with a decrease in ratings of overall alertness and psychological comfort, and an increase in ratings of tension. Differential changes in diastolic and systolic blood pressure on each side of the body were also demonstrated in nonuniform thermal conditions.

DISCUSSION AND CONCLUSIONS

The findings of this investigation point to the possibility of decrements in the work performance of astronauts during extended EVA in nonuniform thermal conditions. Changes in vigilance, inaccurate perception of thermal status of different parts of the body, and decrements in overall psychological comfort and alertness are of concern to mission success. The individual differences noted across subjects in responsiveness to nonuniform thermal conditions suggests the need to evaluate these factors in the management of EVA, and to develop countermeasures to mitigate the effects of these conditions.

THE HAND AS A CONTROL SYSTEM: IMPLICATIONS FOR HAND-FINGER DEXTERITY DURING EXTENDED EVA

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There is broad agreement that the emergence and evolution of species *Homo* was closely associated with the phylogenetic emergence of prehensile hands as advanced, articulated movement systems specialized for complex expressive, social, and instrumental control behaviors. The most recent stage of human social, occupational, and technological evolution into space environments has been accompanied by new challenges to effective behavioral control and use of the hands and upper extremities for the performance of useful work. This paper analyzes the hand as a behavioral control system and explores the implications of this perspective for understanding sources of, and possible solutions to, problems via the dexterous use of hands to perform work during extravehicular activity (EVA) by suited astronauts in space.

Our understanding of the hand as a control system is best seen as a dynamic interaction between task, performer and the environment. Optimal performance of reaching and grasping requires information directly perceived from the "object to be grasped" which mediates both the kinematic and kinetic requisites of the reach and grasp activity. Postural configuration and support is a critical requirement for a successful coordinated reach and grasp activity. Appropriate postural support permits effective use of both the spatial, temporal, and force requirements to complete the task. The coordinated activities of the arm, wrist, hand, and finger system permit a wide range of manipulanda, dexterous, and forceful skill based activities.

From the initial information derived primarily via visual perception, a variety of feedback systems enrich the interaction of the hand-finger system and the object, permitting essentially, a closed loop monitoring of the performance. The system must detect the invariant properties of objects to be manipulated, transported, or torqued via a variety of feedback information that includes haptic and visual information, as well as proprioceptive, tactile, and thermal changes which will allow for optimal or near optimal performance. Such behavior will permit the exercise of a broad repertoire of skillful and force based activities that include grasping, seizing, tracking, steering, reaching, placing, tracing, pointing, beckoning, waving, pushing, pulling, turning, twisting, pinching, squeezing, punching, lifting, supporting, throwing, pivoting, smashing, cutting, tearing, shearing, piercing, pressing, shaping, forming, smoothing, padding, and tapping unilateral and bilateral functions of the hands. Numerous allusions in the lexicon to hand functions underscore the richness of hand movement behaviors that are involved in diverse forms of expressive, gestural, symbolic, social, and tool using activities.

During extended EVA, behavioral control of hand movements typically is compromised for a variety of reasons. The space suit and gloves reduce range of movement and articulation of the arm, wrist, and fingers. Micro gravity conditions may reduce the control stability of postural and transport movements. Integration of hand movements with control of visual, auditory, and social feedback may be compromised because of EVA related perturbations in these latter sensory feedback modalities. Peripheral cooling of the upper extremities may also undermine all modes of movement and sensory feedback. Research evidence indicates that when movement is impaired, control of sensory feedback suffers and effective behavioral control of motor performance is compromised. We may therefore anticipate that during extended EVA the fidelity of dexterous hand control behaviors for routine tool use, expressive, gestural, and social interactive purposes will be constrained. The present report outlines research strategies for delineating the nature and extent of this problem area and will suggest possible approaches to problem abatement.

UNDERSTANDING THE SKILL OF EXTRAVEHICULAR MASS HANDLING

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INTRODUCTION

Our approach to understanding mass handling during extravehicular activities(EVA) is fundamentally empirical and analytically open to the peculiarities of adaptive and intentional control by humans of human-machine systems. We view extravehicular mass handling as a whole-body skill with a domain of adaptability that currently is not well understood. Documentation such as the EVA Lessons Learned [1,2] indicate to us that it is at least as important to understand this adaptability as it is to understand simply what a crewmember can reach. To gain some insight on this capacity for adaptability a ground based investigation of extravehicular mass handling was designed and performed utilizing the Precision Air Bearing Floor at NASA Johnson Space Center.

METHODS

Subjects were suited in a Shuttle extravehicular mobility unit (EMU), pressurized to 4.3 psi. They were placed in a recumbent orientation, left hand down, and supported by a frame attached to the portable life support system (PLSS). This frame was fitted with bearings located along an axis which ran through the center of mass of the human-EMU system and sat in a "cradle" device so as to permit body yaw rotation. The yaw axis cradle-EMU assembly was supported on an air bearing sled. The subjects feet were affixed to a foot restraint (PFR) which was attached to a rigid, immovable structure. Thus the subject, restrained at the feet, could pitch and yaw, and translate in the anterior-posterior and superior-inferior axes by virtue of the air bearing sled and the yaw-axis cradle. In this configuration, subjects' performed an orbital replacement unit (ORU) docking task, maneuvering a 5 degree of freedom (on air bearings) ORU into a docking structure. Trials were repeated with the PFR placed in 6 different locations relative to the docking structure, with varying degrees of freedom permitted for body motion, varying ORU translation trajectories, and under two conditions of docking accuracy. During all of the trials, force and moment data were collected at the PFR and the ORU handle. A video based tracking system was also used to track the motion of the EMU and the ORU relative to the PFR and the docking structure.

RESULTS

We will report data to argue that the essential aspects of mass-handling skill include: (a) management of the tradeoff between postural stability and mobility; (b) control of multiaxis postural perturbations resulting from noncoplanar force couples between ORU and restraints; and (c) sensitivity to the postural and ORU inertia tensors with respect to the ORU trajectory and with respect to the location and orientation of restraints, EMU, and ORU.

CONCLUSION

These data are undergoing analyses in an effort to yield insights that will increase the generalizability of past investigations and current Detailed Technical Objectives (DTOs). The application of these insights is intended to facilitate planning for future EVAs that exploit the skills of crewmembers for whole-body coordination and adaptation.

REFERENCES

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