Chapter 11

MEDICAL, PSYCHOLOGICAL, AND ENVIRONMENTAL ISSUES OF ARTIFICIAL GRAVITY

Jeffrey Jones, Randal Reinertson, and William Paloski

NASA Johnson Space Center, Houston, Texas, USA

American astronauts and Russian cosmonauts have established a presence in space for approximately 40 years. Although most have spent several weeks in space, a few have logged a little over one year. Based upon this experience, flight surgeons have defined the adaptive (physiological and psychological) and maladaptive (medical and psychiatric) effects of microgravity and re-adaptation upon return to Earth. Although a number of countermeasures are being used, they only retard the effects of microgravity. None has proven to be truly effective. This chapter reviews the areas where artificial gravity could be beneficial from the flight surgeon perspective. It also examines the needs for medical monitoring and planned emergencies during studies on artificial gravity.

Figure 11-01. Contour couches were fitted for Mercury astronauts for performing physiological performance tests in the long-radius centrifuges. Flight versions of these couches were also used during spaceflight, for increasing tolerance to acceleration during launch and re-entry. Photo courtesy of NASA.

1 INTRODUCTION

Medical and psychological issues have been a concern for space travelers, even before the first living beings were thrust beyond 100 km, or 62 miles, above the Earth's surface[39]. More concerns were raised when proposals for space travel included altitudes of 120 km above the Earth's surface, especially with the speeds of orbital flights, because of the transition atmospheric thermal effects that are observed with the vehicular deceleration during re-entry. There were many "aviation medical experts", even as late as the 1950's, who felt humans were not adaptable to the space environment, and would become ill, be permanently impaired or even perish, if flown into space. Thus began the field of *space medicine*.

What is space medicine? To quote NASA space medicine leaders: *"Space medicine is the practice of all aspects of preventive medicine including screening, health care delivery, and maintaining human performance in the extreme environment of space, as well as preserving the long term health of space travelers. Space medicine must address numerous challenges to human health including environmental extremes, physiological responses to microgravity, and psychological considerations"* (Pool and Davis 2006).

Another definition espoused by the U.S. Institute of Medicine when reviewing the topic under a NASA-commissioned study states: *"Space medicine is a developing area of health care that has roots in aerospace medicine but that is focused on the health of individuals so that they can perform in, and return in good health from, increasingly distant extreme space environments, for example, from short-duration space flights, long-term space station flights, missions to the Moon, and in the next stages, exploration-class missions beyond Earth orbit, including missions involving planetary colonization"* (Ball and Evans 2001).

Notable pioneers in Space Medicine include Oleg G. Gazenko, Abram M. Genin, Andre Lebedinsky, Vasily Parin, V.I. Yazdovsky in the former U.S.S.R. and Russia. P. Marbarger, P. A. Campbell, Ashton Graybiel, W. Randolph Lovelace, Harry G. Armstrong, and Charles A. Berry were leaders and pioneers in aviation and space medicine in the U.S.A. (Pool and Davis 2006) The same issues that these early space medicine practitioners faced in the 1950's and 60's, current flight surgeons face today. However, since the 50's we have learned a significant amount about the human body's tolerance to the extremes of the space environment. Consequently, we now have a much

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[39] 100 km is also known as the *Karman line*, established as boundary between atmosphere and space by the *Fédération Aéronautique Internationale* (FAI), the standard setting and record-keeping body for aeronautics and astronautics, founded in 1905. The U.S. definition of space is 80 km (50 statute miles), approximately where Mesosphere ends; travelers beyond this altitude are called *astronauts*.

more robust evidence base, from which to pursue a universal countermeasure to microgravity such as artificial gravity.

The description of the environmental hazards of space and the practice of space medicine are described in Section 2. The rationale behind and requirements for medical monitoring of both research and operational utilization of artificial gravity as a spaceflight countermeasure are discussed in Section 3.

2 SPACE MEDICINE

This section is a review of the effects of physiological, medical and psychological factors on crew health, well being, behavior, and performance. This knowledge is helpful for evaluating the hazard of providing continuous or intermittent artificial gravity in deconditioned subjects.

Hazard	***Acute Risk***	***Chronic Risk***
Radiation	*Acute radiation sickness*	*Cataracts, cancer*
Vacuum	*Ebullism, decompression sickness*	*Death*
Microgravity	*Space adaptation syndrome*	*Muscle atrophy, bone loss, neurovestibular dysfunction*
Micrometeoroids/ Orbital debris	*Trauma*	*Plasma*
Toxic exposure	*Acute respiratory distress syndrome (ARDS), confusion, burns, sensory loss (sight, smell)*	*Fibrosis, dementia*
Surface regolith (dust)	*Allergic reaction*	*Pulmonary fibrosis*
Hypoxia	*Confusion, lethargy*	*Acute motion sickness (AMS), loss of consciousness, death*
Hypercarbia	*Headache, dyspnea*	*Confusion, coma, death*
Temperature	*Chilblains, pernio*[40]*, heat exhaustion*	*Frostbite,* *loss of conciousness, heat stroke*

Table 11-01. Hazards and risks associated with the spaceflight environment.

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[40] Chilbains or pernio are inflammatory skin conditions that appear after exposure to extreme cold.

2.1 Environmental Hazards of Spaceflight

The hazards that are unique to the extreme environment of space are summarized in Table 11-01. They include hypoxia, insufficient oxygen and hypercarbia, elevated carbon dioxide in the cabin or spacesuit atmosphere due to impaired performance or failure of the life support system. The life support system is essential for life in space and other planetary surfaces, due to an insufficient atmospheric pressure and oxygen supply for human existence.

2.1.1 Hypobarism

The relative vacuum of space poses a risk of ebullism should the crew be exposed to it, hence the need for a spacesuit while performing *extra-vehicular activity* (EVA). However, in order for crewmembers to perform efficiently in the suit, the pressure should be as low as possible, yet still maintain adequate oxygen tension to avoid hypoxia. Whenever the body undergoes transition to lower pressure environment, there is always a risk of developing *decompression sickness* (DCS) or illness, also known as "the bends". The larger the pressure difference in a nitrogen-rich atmosphere, the higher the risk of DCS developing, unless adequate time is dedicated to pre-breathing 100% oxygen to wash out the nitrogen from the body. The risk of DCS may be lower in microgravity than in 1-g conditions, possibly due to changes in large muscle group shear forces or differences in bubble dynamics. At least the number of observed cases of orbital DCS is less than would be expected based on terrestrial models (Balldin and Webb 2002, Pilmanis *et al.* 2004, Webb *et al.* 2005).

2.1.2 Toxic Compounds

A large number of potentially toxic compounds may be on board the transit and habitation vehicles for a wide variety of functions. Design engineers must trade the use of toxic compounds with a performance track record versus less toxic compounds with potential performance issues, especially in the area of propellants, cooling system, and in-situ resource utilization hardware. For example, fuels for reaction control jets often employ hypergolic components that spontaneously react or burn when mixed together and are effective in the vacuum of space, such as monomethyl hydrazine and nitrogen tetroxide, both of which are highly toxic when inhaled or when contact is made with the mucous membranes. Another example is in the cooling loops where ammonia or ethylene glycol is often effectively used; however, both of these substances have leaked into space station compartments and both have serious effects when breathed or ingested in significant quantities.

As has been experienced on both transit as well as habitation vehicles, e.g., Apollo, Salyut, and Mir combustion events can produce toxic compounds such as hydrogen cyanide, hydrogen chloride, and carbon monoxide. The acute and chronic effect risks of large dose exposure to lunar or Martian regolith dust has also not been fully elucidated, although the topic is under evaluation by NASA toxicologists and physicians.

Both acute and chronic diseases may result from toxic exposures, depending on the duration and magnitude of exposure. These induced conditions range from ocular or respiratory irritation, to unconsciousness and death. The effects of microgravity on the cellular and immune response to toxic compounds has yet to be completely defined, but some evidence would suggest that immune function will be diminished during long-duration spaceflight, and may result in increased risk of secondary microbial infections in tissue damaged by toxic substances (Kaur *et al.* 2004, 2005, Stowe and Pierson 2003). Artificial gravity, intermittent or continuous, could play a role in maintaining immune function, if it is determined that diminished gravity exposure produces alterations in leukocyte gene expression (see Chapter 10, Section 1).

Toxic substances countermeasures include personal protective equipment such as quick-don and portable breathing masks, which protect the crew's mucous membranes and respiratory system, in case of fire or rapid de-pressurization. Known antidotes for likely toxins will be components of medical kits and will include agents such as pyridoxine for hydrazine toxicity, and nitrites with thiosulfate for cyanide poisoning. Eyewashes will be included in the kit for removal of debris or chemicals from ocular tissues.

2.1.3 Radiation

Two classes of radiation pose a hazard to crewmembers, especially while on EVA: ionizing and non-ionizing.

<u>Ionizing radiation</u> can produce damage to human tissue through direct molecular interaction or via the production of free radicals and reactive oxygen species. This damage, depending on the severity and location within the cell can produce cellular lethality or mutation, especially if the radiation affects the nucleic acids. If the dose is high enough in a short exposure period, ionizing radiation can produce *acute radiation syndrome* (ARS), which is divided into three categories: hematologic, gastrointestinal, and central nervous system forms of ARS. Doses high enough to cause ARS are possible from large solar storms (Figure 11-02), especially if the crewmember is not protected by vehicular or habitat shielding. Potential long-term effects on the body resulting from lower doses or more prolonged exposures include cataracts, cancer, microvascular fibrosis, and dementia (Prasad 1995).

Crew defense against ionizing radiation hazards will lie mainly in the form of shielding. This is especially true for protection against the high dose concentrated over a short time interval, which could result from a large and energetic *solar particule event* (SPE) (Figure 11-02, left). The solar protons are much more amenable to shielding than is *galactic cosmic radiation* (GCR) (Figure 11-02, right). Having transit vehicle or habitat shielding that can provide a “storm shelter” in the event of a major SPE, will be an essential design feature (Wilson 1997, Simonsen 1997). Shielding GCR may come in the form of planetary regolith or natural terrain features, which additionally may aid with micrometeoroid protection.

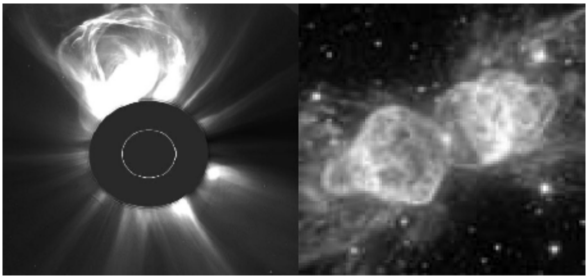

Figure 11-02. Left: Coronal mass ejection from the sun, at the origin of solar protons. Right: Colliding galaxies spewing galactic cosmic radiation.

The development of radioprotectant formulations, or agents that may reduce oxidative damage, which could be administered orally or parenterally, may augment the crew’s defense against some of the ionizing radiation (Stanford and Jones 1999, Lupton 2001, Taylor 1992). Recent studies suggest that microgravity may affect cellular gene expression, and thus may alter the cell’s natural radiation defense and repair systems (Boonyaratanakornkit *et al.* 2005, Purevdorj-Gage and Hyman 2006). This would most likely be a negative way synergy, such that the combination of ionizing radiation and microgravity may produce more biologic impact than ionizing radiation alone. If the observations in these studies prove to be correct, then artificial gravity may play a role in reducing these biological effects, by suppressing the changes in gene expression.

The sources of non-ionizing radiation are chiefly solar, but also include man-made equipment such as lasers and communications antennae, which can produce various forms of electromagnetic radiation. The solar light, ultraviolet, and infrared radiation can be near instantly hazardous to the retinas of crewmembers if their eyes are not protected by special visors which absorb or reflect the harmful wavelengths. This is also true of laser devices flown to assist in range finding during rendezvous and docking of space vehicles as well as exterior inspection, and other applications. The energy density of the laser beam has a large influence of the potential time and severity of biological effects of the laser.

Other forms of electromagnetic radiation, such as microwaves, can produce local tissue heating and thermal injury, if the radiation is of high enough intensity and the crewmember’s body is placed directly in the path of transmission.

2.1.4 Impact

Micrometeoroids and orbital debris constitute a risk of not only hypobarism (DCS and ebullism) but also trauma to the crewmembers, whether they are conducting EVA in space or on the planetary surface. The kinetic energy contained by these small meteoroids can be quite significant, especially at typical velocities of up to 20 km/s, and therefore they can inflict serious harm. Vehicular and space suit design is likely to include energy absorbing strength layers which can resist penetration of micrometeoroids and should have a self-sealing type material in the inner pressure bladder, in case of non-lethal micrometeoroid strike (Jones *et al.* 2004).

2.2 Environmental Hazards Inside the Habitat

2.2.1 Atmospheric Composition

The partial pressure of oxygen must be provided to the crew to prevent development of hypoxic symptoms, and the partial pressure of carbon dioxide must be scrubbed to prevent development of hypercarbic symptoms. A challenge for exploration missions will be the development of *in-situ resource utilization* (ISRU)-based life support technology, and possibly even bioregenerative approaches to atmospheric control. Swing-bed technology with molecular sieves are likely to be used early in maintaining metabolic carbon dioxide at acceptable levels, as this approach does not consume the scrubbing material as is the case with lithium hydroxide used in Apollo and Shuttle environmental control systems.

The atmosphere must also be filtered of particulates and trace contaminants to prevent respiratory irritation. *Spaceflight maximal allowable contaminants* (SMAC) are established to limit levels low enough to prevent development of biological effects of the contaminants.

A unique potential atmospheric contaminant of the lunar or Martian surface will be dust from the planetary regolith. This dust will differ from terrestrial dust in size distribution, shape and chemical reactivity, therefore making it potentially a larger hazard than the nuisance variety found commonly in terrestrial vehicles and living spaces. Some speculate that lunar and Martian dust may have characteristics similar to freshly fractured silica or coal, which can produce not only acute respiratory reactions secondary to deposition in the bronchioles and alveoli of the lung inducing oxidative damage, but also potentially pulmonary fibrosis associated with prolonged exposure.

2.2.2 Water Chemical Contamination

Water chemical contamination will be kept within water quality standards, to prevent ingestion of potentially harmful agents. There have been several incidents during space station missions of water becoming contaminated with elevated concentrations of harmful substances, e.g. cadmium leaching from water system valving and ethylene glycol being accumulated in the water reclamation system from a cooling system leak.

2.2.3 Microbial Content

Vehicular and habitat air, water, and surface microbial content must be kept below standards, as microbes pose a hazard of infectious disease, that is mitigated through the use of biocide and filtration.

2.2.4 Thermal stress

Temperature control will be important not only in the transit vehicle and habitat, due to large temperature excursions during lunar and Martian day-night cycles, but especially in the EVA spacesuit, where slight perturbation in heat loading can rapidly increase thermal stress to the crewmember unless promptly controlled. The use of suit insulation and liquid-type cooling undergarments will likely play a large role in reducing the risk of thermal injury and performance deficits in EVA crewmembers (Waligora 1975). An active thermal control system with connections to heat radiators will assist in maintaining a cabin temperature and dew point.

2.2.5 Noise

Elevated sound levels usually emanating from onboard equipment, can pose hazards to the hearing and psychological well-being of the crew. The best means of reducing these risks is via engineering solutions, to muffle the sound emissions, however when the engineering approaches are not satisfactory, noise attenuation hardware, either active or passive may be employed.

2.2.6 Vibration and Acceleration

Flight vibrations and acceleration are usually only significant during dynamic phases of flight, i.e., launch, orbital maneuvering, transit burns, atmospheric re-entry, and landing. Design limits for vibration and acceleration, specific for the axis of load onto the crewmember should reduce the risk of critical task performance errors. However an important countermeasure for both the neurovestibular and orthostatic adaptations during g-transition phases of flight could be artificial gravity.

2.3 Psychological Hazards

2.3.1 Chronobiology

Due to the rapid sequence of light/dark cycling in LEO, there is a transition every 45 min for orbital periods of 90 min, the crewmembers natural biorhythm is interrupted. Interruption of usual chronobiology will also be expected during lunar surface stays, especially if permanently lit regions of the lunar south pole are chosen for the outpost habitat. Without the natural dark-induced timing of melatonin release of the environment, the vehicle may need to provide dark quarters to allow normal sleep patterns to be acquired by long duration crewmembers. In addition, vehicle docking, relocation and timing for orbital maneuvers, often force crewmembers to be awake during their chronobiologic nadirs, increasing the risk of fatigue-induced crewmember errors. Flight rules have been written in attempt to reduce the risk of fatigue-related task errors, but these rules are often overcome by operational drivers. Supplemental melatonin as well as short-acting benzodiazopines have been used during both Shuttle and ISS flights to not only induce sleep but to re-establish shifted sleep entrainment. Light therapy especially in the blue wavelengths, has been employed to help reduce fatigue during sleep shifting and assist in the establishing new wake-sleep schedules.

2.3.2 Isolation

Long-duration spaceflight places the crew in isolation from their family, friends, and most of their colleagues for months, and in the future for perhaps years. This isolation, as well as the heavy work schedule without effective opportunities for rest and relaxation, can take a toll on crewmember morale and well being (Nicogossian *et al.* 1994, Kanas and Manzey 2003). Risks for depressive symptoms and crew-crew and crew-mission control interaction difficulties increase with the duration, as well as stress-level, of the mission. Countermeasures that have been shown to be effective for long-duration crews include weekly family private conferences, biweekly private psychological conferences with a trained space psychologist or psychiatrist, recreational and personal hardware including musical instruments, DVD players and photo albums of family and friends. Artificial gravity is not likely to have a significant impact on psychological issues during spaceflight.

2.4 Microgravity

Multiple chapters of this text have discussed the changes in human physiological systems associated with the microgravity environment. These changes are expected physiological adaptations to the lack of gravity loading and are not in themselves pathological. Some of the symptoms associated with adaptive changes, such as *space motion sickness* (SMS), require pharmacological intervention, to limit mission impact of the symptoms, especially in first time space fliers (see Chapter 4, Section 3). Typically promethazine administered parenterally is used to treat SMS during the first 48 hours of flight, especially if the nausea and vomiting that are characteristic of the syndrome are severe. Other symptoms such as headache and nasal stuffiness are treated with additional pharmacological intervention as required.

However these adaptive physiological changes to microgravity are not diseases and are not usually treated medically (Nicogossian *et al.* 1994, Clément 2005). Instead, countermeasures are used in attempt to maintain 1-g conditioning so that the transition back to 1 g will be less challenging. Countermeasures for the muscle, bone, and neurovestibular changes are prescribed by the flight surgeons during both short- and long-duration spaceflight, and may include modalities such as exercise (aerobic for cardiovascular protection, resistive for musculo-skeletal protection), lower body negative pressure, fluid loading, anti-g suit, and pressure garment (for orthostatic hypotension protection).

This is where artificial gravity may provide the largest impact to protecting functionality for the crew upon return to a gravity field after prolonged periods in microgravity. Artificial gravity may be particularly effective in preserving the capability to response to an off-nominal landing event whether it be during the landing phase, or the need for emergency response or egress of the vehicle after landing. Additional risk reduction in the area of reduced postflight musculo-skeletal injury may also be conferred by artificial gravity use during flight, especially during the return trip.

2.5 The Role of the Flight Surgeon

The flight surgeon is the "space medicine practitioner" during space mission operations. From the medical perspective, space missions are commonly divided into three major phases: preflight, in-flight, and postflight. Let's examine the duties of the surgeon during each of these phases, so it will become clear how a surgeon's prescription for artificial gravity use may influence the crewmember's health throughout the mission.

Prior to beginning preparation for a space mission, the flight surgeon as part of an aeromedical board of physicians, will assess an astronaut applicant's health for selection to the astronaut corps, according to the medical standards. Each year following selection, the health of each astronaut will be evaluated for medical retention, which includes medical certification for training and flight in training aircraft. Prior to assigned spaceflight, each astronaut will be medically certified for duty on that vehicle. Crewmembers flying to the ISS will be certified by the *Multilateral Space Medicine Board* (MSMB) composed of representatives from the major partners of the ISS program.

2.5.1 Preflight

During the preflight certification process, the crewmembers are tested biochemically and microbiologically, and appropriate preventive measures are taken including immunizations and treatment of any infectious conditions. The *Astronaut Strength, Conditioning, and Rehabilitation* (ASCR) team will work with the crew during the 6-12 months prior to flight to optimize their physical conditioning and prepare muscle groups that our prone to fatigue during flight task like EVA.

During the preflight training period, the flight surgeon serves as the medical monitor and support for any physiologically stressful training activities. This includes training in the neutral buoyancy laboratory or hydrolab, where weightlessness is simulated for EVA, vacuum chamber runs, water and winter survival training. If artificial gravity is adopted as an in-flight countermeasure, then the preflight training and familiarization will also be supported by the flight surgeon.

The mission's assigned crew surgeon is also responsible for training the *Crew Medical Officer* (CMO) on the contents and operations of the medical system. Training also includes reviewing the procedures within the medical checklist, how to perform a private medical conference while in-flight, and how to handle a medical contingency should it arise.

A period of health stabilization and maintenance is entered approximately 10 days to two weeks prior to launch, to remove the crew from large vectors of infectious diseases as well as protect their time to focus on specific preflight preparation activities.

If the launch window or flight operations require the crew to be awake during nominal sleep periods, then the crew's sleep must be shifted in advance and a new anchor sleep time established prior to launch, to allow the crew's in-flight performance to be maintained at an optimal level. This process requires more advanced implementation if the magnitude of sleep shift is large. Sleep shift aids such a light therapy and melatonin may be employed, depending on the direction of the time shift.

The medical flight certification process also includes review and concurrence with the engineers that the medical hardware and kits are also ready to support the mission.

2.5.2 In-Flight Health Maintenance

The crew and deputy crew surgeons and biomedical engineers are on console at both the launch control and mission control centers for launch activities, and have communication networks open with search and rescue forces, provided by both NASA and the department of defense, in case of a launch abort or contingency. The surgeon is a front control room console position and provides a Go/No-Go recommendation for various phases of launch, landing and flight activity to the flight director.

The surgeon is responsible for enforcing the aeromedical flight rules concerning the crew health and safety concerns during flight, which includes responses to off-nominal space environment, such as atmosphere and water. The surgeon also enforces many of the ground rules and constraints, especially related to crew scheduling, to prevent jeopardizing crew safety secondary to mission overload.

Private medical conferences are conducting with the crew daily during short duration flight and on a weekly basis during long duration missions. The surgeon and biomedical engineer will be on console to medically monitor all EVAs and onboard medical or life science research activities, in which the crew is acting as a subject. During EVAs the medical team will receive biomedical telemetry from sensors worn underneath the cooling garment, so that they can track not only the level of carbon dioxide and thermal loading, but also heart rate and rhythm, metabolic rate based on oxygen utilization, carbon dioxide or heat production, and in some cases, like when Russian space suits are used, respiratory rate and body temperature. Future seats may build such sensing equipment into the cooling garment or maybe even a subcutaneous chip to allow these parameters to be monitored without overhead. Perhaps during Mars missions, the biomedical information will be locally processed with software algorithms which allow prediction of remaining consumables such as oxygen or water, to feed back to the crew for optimization of task performance or ambulation rate, or to caution the crew when off-nominal or life-threatening situations arise.

During long-duration flights in LEO, currently there are regularly scheduled periodic health assessments, consisting of monthly or bi-monthly examinations and laboratory tests of the urine and blood. A portable clinical blood analyzer and urinalysis testing hardware is flown to provide diagnostic and biochemical status information. Periodic fitness evaluations are conducted monthly to evaluate effectiveness of the in-flight countermeasures program. The crew surgeon, working with the ASCRs as mentioned above, provide exercise and other countermeasures prescriptions to the crew during the flight (Figure 11-03), and tailor the prescription based on in-flight assessment tools like the *pulmonary functional evaluation* (PFE), or, in the future, blood tests or imaging. Future countermeasure prescriptions for missions to Mars may include pharmaceutical agents, like bisphosphonates, or physical agents, like artificial gravity, if the results from current research prove promising.

The flight surgeon, working with nutritionists and food systems experts, reviews the content of the planned crewmember's diet as well as preflight nutritional testing to ensure adequate levels of nutrients are supplied to maintain health and to resist disease (Lane 2000, Watson 1996). Due to several factors, e.g., lack of sunlight exposure, prior long-duration crews have had reduced levels of vitamin D found in postflight measurements, so levels of this nutrient may need to be supplemented (see Chapter 9, Section 4.1).

The medical team is also responsible for environmental monitoring, and along with the environmental control team and specialists in toxicology, radiation, and water quality. There are periodic or continuous assessments of the vehicle environmental parameters. If these parameters should be found to be outside of acceptable limits, then the surgeon may need to invoke a flight rule, which could require the initiation of on-board corrective actions.

Figure 11-03. Expedition 13 Astronaut Jeffrey N. Williams, equipped with a bungee harness, gives a "thumbs-up" signal while exercising on the Treadmill Vibration Isolation System *(TVIS) in the Zvezda Service Module of the International Space Station. Photo courtesy of NASA.*

2.5.3 In-Flight Medical Events

Despite the rigorous screening and preventive medical approach to spaceflight, medical events occur very commonly, as was discerned from a review of the Space Shuttle flights between 1981 and 1998, comprising 89 missions and 508 crewmembers (439 men, 69 women), in which 98% of crew reported some medical symptom during their flights. A listing of symptoms affected during short duration missions is as follows: 67% headache, 64% respiratory complaints, 58% facial, nasal and ocular complaints, 32% gastro-intestinal complaints, 26% musculo-skeletal complaints, 12% injuries, 10% genito-urinary symptoms. In addition, 79% of the crew suffered from SMS within the first few days of entering microgravity (Jones *et al.* 2004).

The experience for long-duration crewmembers is not dissimilar from short-duration fliers. However, difficulties with skin rashes and abrasions, foreign bodies in the eye, sleep disorders, and interpersonal issues occur at a higher rate. Also during long-duration flight there is a higher rate of musculo-skeletal symptoms and equipment discomfort issues associated with the use of countermeasure hardware. Dental symptoms have arisen on several long-duration missions, especially when preflight dental issues existed.

Medical conditions with an expected incidence of greater than 50% include skin rash, irritation, foreign body, eye irritation, corneal abrasion, headache, backache, congestion, gastrointestinal disturbance, cut, scrape, bruise, musculo-skeletal strain, sprain, fatigue, sleep disturbance, space motion sickness, post-landing orthostatic intolerance, post-landing neurovestibular symptoms (Davis 1998, Jones *et al.* 2004).

There have been three medical evacuations during spaceflight from Russian space stations. These evacuations occurred: (a) during Salyut-5 in 1976 the station was abandoned 49 days into a planned 54-day mission for intractable headaches; (b) during Salyut-7 in 1985, there was one crewmember evacuated at 56 days into a 216-day mission for prostatitis-induced sepsis; and (c) on Mir in 1987 a crewmember was evacuated 6 months into a 11-month mission for a cardiac dysrhythmia.

There have also been multiple close calls occurring near evacuation or mission termination in both U.S. and Russian programs. For example, there have been spacecraft fires in 1967 (3-U.S. fatalities in Apollo 1), 1971, 1977, 1988, and 1997 (the latter occurred on board Mir due to an oxygen generator); a urinary stone in 1982 on Salyut-7, which passed spontaneously just prior to an evacuation; hypothermia during EVA in 1985; psychological stress reaction in the mid 90's; spacecraft depressurization in 1997, with collision of a Progress vehicle with the Spektr module of Mir; toxic atmosphere on two occasions in 1997 with inhalation of smoke during the fire and later an ethylene glycol release from the cooling system (Jones *et al.* 2004).

Radiation sickness has not occurred in-flight. However on August 4, 1972, i.e., less than four months after Apollo 16 returned from the Moon and three months before Apollo 17 launched, there was one of the highest magnitude SPEs on record. If a crew had been in interplanetary space during that SPE, with the limited shielding on the Apollo command module, estimates are that they would have experienced acute radiation sickness, possibly severe (Townsend 2003). The treatment requirements for a crew in the case of a high dose and rate radiation exposure is significant, and possibly beyond space medicine's ability to treat, unless new protective strategies are developed.

The occurrence rate of medical conditions requiring urgent medical intervention from expeditions in remote environments, analog simulations, and in the highly medically selected and maintained U.S. astronaut corps, both terrestrial and in-flight, have been compiled by Dr. Smith Johnston and others, looking at the medical requirements for crew rescue vehicles like the

Crew Return Vehicle (CRV-X38) and the Orbital Space Plane. This analysis reveals a 7% (5-10%: 90% CI) probability of a serious medical event per man-year. More crewmembers and missions of longer durations cumulatively increase that probability (Jones *et al.* 2004).

The very nature of exploration, especially on a minimally explored planet, has taught us that traumatic accidents will be highly likely, even with the best of precautionary procedures and safety algorithms. The real possibility of blunt and penetrating trauma, crush injuries, deceleration injuries, hypobarism injuries, and burns cannot be underestimated. Treatment protocols and capabilities should be expanded beyond the current advanced cardiac life support on board the ISS, to include advanced trauma life support for lunar outpost and Mars missions.

In order to maintain readiness to respond to a medical condition, there will be medical computer-based training and skills maintenance tools flown Examples include medical and surgical procedure simulators with realistic feedback on performance.

- *Potential illnesses and problems*
    - *- Musculo-skeletal problems*
    - *- Infectious, hematological, and immune-deficiency associated conditions*
    - *- Dermatological, ophthalmologic, and ENT problems*
    - *- Dental*
    - *- Psychiatric conditions- stress reaction, interpersonal conflict*
- *Acute medical emergencies*
    - *- Wounds, lacerations, and burns*
    - *- Decompression Sickness (DCS)*
    - *- Surgical emergencies - e.g. appendicitis*
    - *- Acute Radiation Sickness (ARS)*
    - *- Toxic exposure and acute anaphylaxis*
- *Chronic diseases*
    - *- Radiation-induced sequelae*
    - *- Responses to dust exposure, pneumonitis*
    - *- Chronic hypersensitivity skin reactions, possibly fungal*
    - *- Urinary calculi – can manifest acutely*
    - *- Latent virus reactivation*

Table 11-02. Summary of potential Moon and Mars expedition medical contingencies.

To summarize the medical events discussion, there is a high likelihood that each crewmember will have minor medical complaints that will need attention to minimize discomfort and maximize crewmember performance. There is a strong probability that a significant medical event requiring urgent intervention to prevent an unfavorable outcome will occur, including morbidity and even mortality. The medical support program for exploration missions should provide for health maintenance, acute condition diagnosis, and treatment for a wide range of medical conditions, trauma, and environmental exposures.

Figure 11-04. Medical contingency simulation at Haughton Crater, in the high arctic.

2.5.4 In-Flight Medical Hardware and Supply

The exploration medical hardware can be classified as ambulatory or emergency. The **ambulatory medical hardware** will include a data management and archiving analytical computer for recording all health-related information, including all preflight test data, and baseline images, for computer analysis and comparison. Diagnostic assist software will be programmed with algorithms for diagnosis and management of many symptoms and signs to assist the crew surgeon in medical and psychological complaint evaluation, in other words, a virtual consultant. This computer will also have a communication package for relay of medical information from field sites, possibly in a pressurized EVA rover to the planetary habitat and to Earth for telemedical consultation with Earth-based specialists.

The diagnostic suite will likely include a telemedicine instrumentation unit for electronic capture of all examination vital signs and photography of relevant anatomy. Other examination hardware may provide for electronic data file stowage, e.g. from a stethoscope, blood pressure cuff, which will facilitate computer-assisted diagnostic review and comparison to baseline information. Medical imaging may include a portable ultrasound unit, or perhaps more advanced imaging devices will have been miniaturized to reduce power and mass requirements and allow placement in the habitat. There will be ambulatory treatment medications for all commonly occurring, non-urgent conditions, including SMS treatment.

Emergency medical hardware to support full resuscitation protocols will be on-board providing the capability to perform defibrillation, suction, rapid fluid or blood replacement infusion, and other critical functions. A reduced gravity operating area, possibly with robotic assistants, will provide basic surgical therapy in both the transit and surface vehicles. Due to the potential for DCS, especially with gravitational ambulation on the lunar and Mars surface, hyperbaric treatment capability will developed, although not likely to provide terrestrial standard of care. Remote medical evaluation capability may be built into the surface rover vehicle, to allow the "away EVA team" to send back medical data to the crew surgeon who may be at the base camp. Figure 11-05 shows a concept for remote medical assessment station, with robotically controlled scanning and visualization hardware.

Despite all of the medical capability and training that will go into preparing for medical contingencies, the crew will need to be prepared both physically and psychologically for the possibility of the death of one or more of their crewmates. A means to contain a deceased crew, which will include a seal from air and fluid exchange, may be included to allow body stowage and transport; however, the possibly of a non-terrestrial burial may be considered because of logistics reasons.

Figure 11-05. Artist Pat Rawling's rendition of a Mars medical assessment station.

2.5.5 Postflight Rehabilitation

There will likely be no quarantine for crewmembers returning from the lunar surface, based on the Apollo experience and the lack of microbes found there. However a successful return of crews from Mars will be a milestone event in history, yet will require a detailed protocol for both quarantine and reverse quarantine of these crewmembers. This will be the case at least for the first crew, who will return to a level-5 containment facility, to prevent back contamination of potential Martian microbes. The crewmembers will also need to be protected from terrestrial bacteria and viruses until their immune systems are functionally nominally again.

After an extensive program of postflight medical and psychological testing, which will provide data for both the crewmember's flight surgeon and for medical research, the crew will embark on a three to six month long rehabilitation program, which will likely include massage, hydrotherapy, and progressive ambulation. Activities of daily living assistance may be employed during the first week. Subsequently, after medical clearance, they will begin a progressive program of increasing loads for both aerobic and resistive exercise to bring their strength, endurance, and bone mineral levels back up to baselines. Due to the social and political importance of the event, there will be extreme pressure from the media for commentary from the crew. The first interviews will need to be conducted from the quarantine facility. It will be challenging to meet the demands of media event requests while simultaneously protecting the crewmember's health and time for postflight debriefs and rehabilitation.

The requirements for the medical support program for space missions flow from medical standards documents such as the *Spaceflight Crew Health Standards Document* and the *Astronaut Medical Evaluation Requirements Document*. These documents supply the medical levels of care and fitness for duty standards that space vehicle program managers must comply with to ensure that the crewmembers occupying and operating those vehicles are healthy and safe to perform their mission tasks.

Even the best medical support and countermeasure system cannot mitigate all of the health risks of spaceflight. In 2001, a committee of the U.S. Institute of Medicine was tasked to create a vision for space medicine during travel beyond Earth Orbit. This committee concluded its report by stating that: *"Space travel is inherently hazardous. [...] The risks to human health of long-duration missions beyond Earth orbit, if not solved, represent the greatest challenge to human exploration of deep space. [...] The development of solutions is complicated by lack of full understanding of the nature of the risks and their fundamental causes".* The main objective of the space medicine organization of tomorrow may well be to develop and validate all of the countermeasures required to enable human exploration of the solar system. Artificial gravity may be a key component to that countermeasure system for exploration-class missions.

3 MEDICAL MONITORING DURING ARTIFICIAL GRAVITY STUDIES

Continuous medical monitoring is necessary for centrifuge operations that expose subjects to high g and high g-onset stresses, such as those that are commonly used in training pilots for air combat maneuvers (Figure 11-06). While subjects in artificial gravity studies are generally exposed to less severe accelerations, many of the potential medical issues are the same and the approach to medical monitoring is similar. Most test protocols require the presence of a monitoring physician and have predetermined test termination criteria, which may vary somewhat depending on the specifics of the study. Vigilant monitoring and a timely response are necessary to effectively intervene for the most common problems resulting from the physiologic stress of centrifugation, including motion sickness, pre-syncope, and cardiac arrhythmias. In addition, centrifuge personnel must possess the appropriate training and equipment necessary to provide effective initial care to injured test subjects and those who develop any unforeseen serious medical issues.

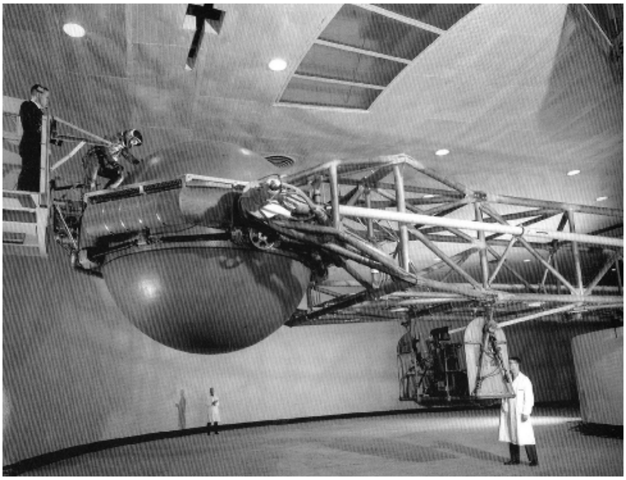

Figure 11-06. The first long-radius human-rated centrifuge used in Mercury astronaut training program at the U.S. Navy Aviation Medical Acceleration Laboratory, Johnsville, Pennsylvania. Mercury Astronaut Walter M. Schirra prepares to enter the gondola of the centrifuge. Photo courtesy of NASA.

3.1 Syncope

For a subject on a centrifuge, presyncopal symptoms and syncope are usually caused by venous pooling in the lower body as a direct consequence of the gravity gradient along the subject longitudinal axis (Gz). Venous return is inhibited, resulting in reduced cardiac output and cerebral hypoperfusion. The gradient necessary to induce syncope on a short-radius centrifuge varies according to individual tolerances, the specific centrifuge configuration, and the onset rate. One study with supine subjects on a short-radius centrifuge revealed that cardiovascular responses to the gravity gradient becomes significant when gravity level at the feet (Gz) is about 1.5 g (Hastreiter and Young 1997). In this study, subjects had the tops of their heads at the center of rotation and the authors reported that syncope occurred in some subjects when as little as 2 g was applied to the feet. A previous validation study of a centrifuge design in which supine subjects had their legs flexed and their heads 66 cm from the rotation axis showed that as much as 6.4 g was tolerated (Burton and Meeker 1992). This same study showed that a gradual onset rate (0.1 g/s) was better tolerated than a more rapid onset rate (1 g/s).

It should be noted that the mechanism of orthostatic stress-mediated syncope seen in subjects on short-radius centrifuges is different than that of

G-induced loss of consciousness (G-LOC). G-LOC is an important issue in high performance and military aviation and has been extensively investigated in high performance centrifuges. The mechanism of G-LOC is thought to be primarily due to a sudden hydrostatic pressure drop associated with rapid onset high-Gz acceleration, because venous pooling is limited by the use of anti-g garments (Self *et al.* 1996). In short-radius centrifuge, the onset acceleration does not exceed a fraction of g/s. Despite differences in mechanism and the usual rate of onset, the resulting decrease in cerebral blood flow causes essentially the same neurologic symptoms in both cases. Therefore, the medical monitoring modalities are essentially the same as those used for high-performance centrifuge operations.

3.2 Prodromal Symptoms

Prodromal symptoms[41] may include a narrowing of the visual field (tunnel vision), pallor, weakness, light-headedness, impaired hearing, nausea, yawning, and a feeling of warmth or cold. Continuous communication with the subject via an audio communications loop is the most effective means for assessing symptoms of pre-syncope (Figure 11-07). Subjective numerical scales may be used to rate nausea and general well being. Video monitoring may be useful by allowing the medical monitor to directly assess diaphoresis, pallor, or repeated yawning.

The onset of tunnel vision can be recognized by using a simple assessment tool known as a light bar. This device has been used in high-g centrifuge operations to detect imminent G-LOC. A typical light bar configuration has two green lights located 35.5 cm laterally to either side of a single central red light. The central light is positioned at a fixed distance (76 cm) from the subject's face. The subject is instructed to focus on the central red light and note any subjective decrease in brightness of the green lights, indicating the onset of peripheral vision loss.

3.3 Heart Rate

Other helpful monitoring modalities include continuous *electrocardiography* (EKG) tracings and blood pressure measurements. In addition to monitoring for arrhythmias, the EKG is a reliable means to continuously monitor the heart rate. A sustained baroreceptor-mediated increase in heart rate is expected during centrifugation. The percentage increase compared to that for a supine subject can easily be 40-60% and is dependent on the applied g level (Vil-Viliams *et al.* 2004, Miyamoto *et al.* 1995). This is a similar

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[41] *Prodromal symptoms* are symptoms symptomatic of the onset of a medical event or a disease.

response to that observed for long-arm centrifuges (Vettes *et al.* 1980) and is presumably associated with a comparable decrease in stroke volume.

An anticipatory increase in heart rate just prior to centrifugation is sometimes seen, particularly for novice subjects. While tachycardia in the 100 to 140 beats/min range may be tolerated for 30 to 60 min or more by many subjects, those who experience progressive increases in their heart rate should be monitored closely for signs of decompensation.

The phenomenon of bradycardia that is occasionally seen during sustained high-g exposure may not be as common during artificial gravity centrifugation because anti-g straining maneuvers and anti-g suits are generally not used (see DeHart and Davis 2002 for review). However, most protocols appropriately call for termination of a test if sudden-onset bradycardia is noted. Such a rapid decrease in heart rate during centrifugation would likely be associated with a significant and abrupt decrease in cardiac output and syncope. The medical monitor should keep in mind that a rapid deceleration (1 g/s) and the associated sudden increase in venous return and reduction in sympathetic tone may actually exacerbate sinus bradycardia by slowing conduction through the *Atria-Ventricular* (A-V) node (Zawadzka-Bartczak and Kopka 2004). Therefore, a moderate deceleration may be more appropriate.

Figure 11-07. Close-up view of Astronaut M. Scott Carpenter, primary pilot for the Mercury-Atlas 7 mission, during centrifuge training at the U.S. Navy Aviation Medical Acceleration Laboratory, in Johnsville, Pennsylvania. Photo courtesy of NASA.

3.4 Blood Pressure

Blood pressure is usually monitored intermittently with an automated sphygmomanometer system. Photoplethysmography has been successfully used to measure blood pressure on a continuous basis during centrifugation (Serrador *et al.* 2005, Vil-Viliams *et al.* 2004) and the use of a tonometry device (Jentow®, Colin) has been reported (Iwasaki *et al.* 1998). However, these devices are generally less reliable than traditional sphygmomanometry and a traditional blood pressure cuff system should be used as a backup device. Invasive methods of blood pressure monitoring have generally been considered inappropriate for this application.

Published reports of blood pressure changes with the onset of short-radius centrifugation have shown a somewhat inconsistent pattern. For example, the study by Miyamoto *et al.* (1995) showed an increase in mean arterial blood pressure that paralleled the increase in gravity level during onset and rose from about 70 mmHg to 90 mmHg with the application of 2.2 g along Gz. Another study reported very small decreases in systolic blood pressure along with slight increases in diastolic blood pressure (Vil-Viliams *et al.* 2004). A third study showed a statistically significant but small decrease in pulse pressure that was primarily attributable to increased diastolic blood pressure with the application of Gz acceleration (Hastreieter and Young 1997).

Figure 11-08. A technician reaches across the arm of a high-g centrifuge to prepare two subjects for a test run.

For medical monitoring purposes, it is probably sufficient to check that the measured blood pressure remains fairly stable after the centrifuge reaches a constant speed. Formal termination criteria generally include a lower limit on systolic blood pressure (e.g., 70 mmHg) and may add a combination of other conditions to define hypotension (e.g., systolic blood pressure below 90 mmHg and tachycardia as greater than 140 beats/min, or a fall of systolic blood pressure by 25 mmHg). In general, it is difficult to detect a sudden fall in blood pressure with intermittent measurements before presyncopal symptoms are apparent. Continuous blood pressure monitoring may be somewhat more helpful, provided the measurement device is sufficiently reliable.

In all centrifuge operations, the signs and symptoms of pre-syncope should ideally be recognized early enough to prevent progression to syncope. Rapidly worsening symptoms are a clear indication for test termination. Mild or slowly progressing symptoms can sometime be ameliorated by muscular contractions of the lower extremities. This can often be accomplished by having the subject perform shallow knee bends or push his or her toes against a footplate. The rationale for this approach is supported by results showing that lower body exercise at least partially protects venous return (Caiozzo *et al.* 2004).

If the subject experiences syncope before a test can be terminated, recovery should occur rapidly, either during or shortly after deceleration. It should be remembered that myoclonic jerks often occur both in cases of G-LOC and neurally mediated syncope (DeHart and Davis 2002, Kapoor 2000). Therefore, it is not necessary to begin an extensive workup for underlying issues unless the subject has a focal neurologic deficit, headache, some other finding consistent with a seizure (e.g., post-ictal confusion), or the concurrent presence of a dangerous arrhythmia.

3.5 Motion Sickness

Motion sickness symptoms generally progress in a predictable order from lethargy to apathy, stomach awareness, nausea, pallor, cold sweats, retching and then vomiting. Other possible symptoms may include salivation, headache, eructation, warmth, flatulence, and anorexia. The traditional theory explaining the mechanism of motion sickness is that it results from a conflict in sensory inputs. The relevant issue here is the fact that in an artificial gravity environment Coriolis forces act on the endolymph in the vestibular system when the semicircular canals are moved into or out of the plane of motion. This creates illusory tilt sensations and nystagmus that can then trigger motion sickness (See Chapter 4, Section 3). Pitch head movements are apparently more provocative of symptoms than yaw movements (Young *et al.* 2001). Transient heart rate increases have been noted to occur after head movements (Hecht *et al.* 2001, Young *et al.* 2001).

In order to avoid provocation of symptoms, subjects should be reminded to avoid head movements whenever possible while the centrifuge is in operation. If movement is necessary, it should be done as slowly as possible. Subjects who are participating in protocols that require repeated centrifugation should be expected to experience some adaptation to the rotating environment (Young *et al.* 2001). A subjective numerical assessment scale is often useful in gauging the severity of symptoms. Progressive or severe symptoms require test termination. A relatively slow deceleration is often more comfortable for the subject. Rapid decelerations should be reserved for subjects who have progressed to emesis and for whom aspiration may be a concern.

3.6 Cardiac Arrhythmias

In addition to rate monitoring, the continuous monitoring of an EKG will give an indication of rhythm or conduction disturbances. Lead systems that use two mutually perpendicular leads, such as biaxillary leads and a sternal lead or a modified chest lead configuration, have proven to be adequate for monitoring purposes. Although it was not a requirement early on in the history of centrifuge training, electrocardiographic monitoring of subjects in high performance centrifuges has become standard because the publication of a study that documented the high frequency of arrhythmias in normal subjects exposed to standard Air Force training profiles (Whinnery 1990). Subsequent studies have confirmed that high-g-induced dysrhythmias are very common, with more than 90% of fighter aircrew exhibiting some sort of rhythm disturbance during high-g training profiles. Sinus arrhythmia, defined as a rate variation corresponding to more than 25 beats/min between successive beats, is the most common dysrhythmia and occurs in approximately 50-80% of aircrew at some time during standard high-g centrifuge training. Isolated *premature ventricular contractions* (PVCs) are the second most common arrhythmia, occurring about 60% of the time. Other arrhythmias, such as *premature atrial contractions* (PACs), sinus bradycardia, ectopic atrial rhythms, junctional rhythms, bigeminy, trigeminy, and A-dissociation are also commonly seen (DeHart and Davis 2002, Hanada *et al.* 2004).

Most arrhythmias occur during simulated air combat maneuvers or rapid onset +Gz exposure. Because the profile usually used in artificial gravity studies are much less severe and do not involve anti-g straining maneuvers, the overall frequency of arrhythmias is much less. However, it is still important to distinguish benign arrhythmias from those that may either indicate underlying cardiac disease or increase the risk for such dangerous rhythms as prolonged sinus arrest, A-V dissociation, ventricular fibrillation, or sustained ventricular tachycardia. A recent article by Hanada *et al.* (2004) analyzed data from the centrifuge training records of 195 male fighter pilots that was accumulated during a two-year period by the Japan Air Self-Defense Force Aeromedical Laboratory. Using their accumulated clinical experience and other considerations, such as a modified version of the Lown criteria to rank the clinical risk associated with ventricular ectopy, this group proposed some criteria for suspending high-g training on the basis of arrhythmias. They grouped the arrhythmias into three broad categories, as shown in Table 11-03.

This approach is similar to that used in many protocols for artificial gravity studies (see, for example, Iwasaki *et al.* 1998). In terminating a centrifuge run, the medical monitor should determine the rate of deceleration appropriate for the specific arrhythmia. Many of the critical arrhythmias, such as ventricular fibrillation, may require basic or advanced cardiac life support interventions. In those cases, a rapid deceleration to avoid delay in treating the subject is appropriate. A rapid deceleration may also be helpful in breaking the re-entry circuit of *paroxysmal supraventricular tachycardia* (PSVT) (Zawadzka-Bartczak and Kopka 2004), but will likely exacerbate sinus bradycardia.

Category	***Action Required***	***Type of Arrhythmia***
Normal physiological response	*Continue centrifuge protocol*	• *Sinus Arrhythmia* • *Occasional PVCs* • *Occasional PACs*
Borderline	*May require discontinuation of centrifuge training*	• *Frequent PVCs* • *Frequent PACs* • *PVCs in pairs or triplets (bigeminy, trigeminy)* • *Non-sustained VT* • *Mobitz type I AV block*
Critical	*Centrifuge training contraindicated*	• *Atrial fibrillation* • *Atrial flutter* • *PSVT* • *Sustained VT* • *Ventricular fibrillation* • *Sick Sinus Syndrome* • *Mobitz type II AV block (or higher)* • *Cardiac Arrest*

Table 11-03.Criteria used for suspending high-g training on the basis of arrhythmia. PVC: Premature ventricular contraction, PAC: Premature contractions in the atria, PSVT: Paroxysmal supraventricular tachycardia, VT: Ventricular tachycardia. Adapted from Hanada et al. *(2004).*

It is useful to set predetermined termination criteria for some of the borderline findings, such as defining more than 30 PVCs per hour or more than 6 PVCs in a single minute as frequent, for the purposes of a study. Other termination criteria based on EKG findings should include ST elevations or depressions and PVCs that fall on the T-wave of the previous beat (R on T). A maximum limit on tachycardia (e.g., greater than 180 beats/min) should also be set. It should be noted that T-wave changes, including flattening, inversion, and the appearance of biphasic T-waves are often seen at the beginning of high-g runs and generally disappear later in the run (DeHart and Davis 2002). These are generally not considered to be termination criteria for high-g centrifugation. This phenomenon has not been reported in artificial gravity studies and it is unclear if this should be considered a benign finding in that setting.

4 EMERGENCIES

Adequate planning for emergencies must be done in advance. While the likelihood of a cardiac or respiratory arrest may be low for adequately screened subjects, centrifuge personnel should be prepared to provide at least basic life support care and defibrillation. The need for advanced cardiac life support capability would depend on the immediate availability of emergency medical services. Advanced planning for evacuation of the subject from the facility and possible transfer to a hospital setting should be carried out. Frequent drills involving all responsible personnel should be a part of the regular schedule.

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