# Gravity and Hypergravity

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## Abstract

"There is much that is not known about how gravity is sensed and translated into input to every system in the body. This includes its required threshold, frequency, intensity, duration and direction. Space provides the ideal environment to tease out these aspects of gravity. This is crucial so that we may understand the requirements for replacing gravity in the countermeasure formula for exploration missions as well as expanding our knowledge in basic human physiology on Earth." Hippokratia 2012……

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The influence of gravity in human physiology has been grossly underrated. From the beginning of human spaceflight it became apparent that changes induced by living in microgravity required measures to protect astronaut health. With durations lasting up to six months and better diagnostic techniques, it is now documented that living in space accelerates by as much as 10 times the rate of decrease, for example, in bone, seen in the average population on Earth.

Countermeasure approaches for the last 50 years have been only partially effective. What is the missing factor? Maintaining Earth-normal physiology requires gravity. No amount of exercise countermeasures can replace changes in posture and their influence on the cardiovascular system or the directional acceleration stimulation of the brain and nervous system that living and moving in Earth's gravity constantly provides. The fact that current CMs without gravity are inadequate helps us appreciate, as we do in plants, that humans rely on gravity for their physiological health. Yet we do not fully understand how different body systems rely on gravity as a controlling or enabling stimulus. Going into space, coupled with essential ground research, has made it possible to begin to answer these questions.

### The case for Artificial Gravity

From the beginning of the space program 60 years ago there have been numerous studies and recommendations proposing the use of artificial gravity inside or in the design of the spacecraft. Engineering ingenuity has come up with rotating spaceships or tethered spinning designs or onboard rotating centrifuges including human powered machines.(Buckley et al 2007)

But the problem is not so much how to design such a machine as to developing and providing the requirements for it and its use that will fulfill the physiological needs of the weightless human body in space. This requires multifactorial, systematic discovery of the way the body perceives the gravity stimulus for optimal effect: – How much? How often? How long? Time of day? With or without activity or other stimulus? Which type of activity? For which physiological system? In which direction? If the intensity of the gravity stimulus provided is greater than 1G, what is the time/physiological effectiveness relationship of hypergravity to that of 1G? Our record has not been strong at 'guessing' answers to these questions because the thinking applied comes from exercise physiology which is probably not the best model. Though there is literature in bed rest studies applying exposure to centrifugation as a countermeasure the same exercise research mentality has been used – exposure once a day usually at levels greater than 1G. The results as with exercise have been consistently partially effective. Artificial gravity as a countermeasure to space-flight deconditioning should be effective, comprehensive, protecting more than one system, require minimum time user-friendly to the crews and with minimal or no side-effects. A systematic comprehensive research program initially on the ground with confirmation in flight is required with a fresh approach. Systematic requires dose-response considerations and a fresh approach requires the recognition that to mimic the exposure to the gravity vector on Earth requires determining thresholds, with multiple exposures, multidirectional taking into account that when a centrifuge stops in space, unlike on Earth the human reverts to subthreshold microgravity unlike on earth where gravity is ever-present.

**What do we know?**

Gravity pulls in one direction only, downward, towards the center of the Earth. Unlike plants, humans have the choice of orienting themselves relative to the force of gravity in every conceivable way and mostly in intermittent patterns. They also reduce gravity's effects on the body during sleep at night or in continuous bed-rest when they are lying in bed. They can also enhance its force with various activities such as walking, running, jumping, bouncing on a trampoline or riding on a centrifuge. How we sense and use gravity is involved in maintaining health and fitness. The most evident is that of *loading* which imparts weight to the body when gravity is pulling in the head to foot direction (+Gz). We are aware of exertion against the force of gravity during normal activity of moving and walking. Gravity is obviously involved in providing the element of postural and other *change* in movement and direction such as directional cues about our spatial orientation relative to gravity's vertical pull.

Without regular exposure to these +Gz forces, as during spaceflight (Clement 2005) and bed-rest (Sandler and Vernikos, 1986) significant cardiovascular, musculoskeletal, metabolic, neural and primarily neuro-vestibular mediated functions are compromised. A study of intermittent standing or walking during bed-rest has indicated the importance of repeated and intermittent gravitational postural stimulation throughout the day is needed rather than one daily exposure (Vernikos et al 1996).

Past research focused on varying the characteristics of the G stimulus such as intensity and direction. However, many other variables such as gender, age, time of day, health, fitness and genetics have not been studied though they would be expected to affect the sensitivity to the gravitational stimulus.
The study of the dose response of accelerations lower or greater than 1g need to be established, not only to determine the sensitivity threshold to 1g on Earth but to explore potential clinical applications. These could include osteoporosis, accelerating bone fracture healing from sports injuries or in the elderly or praplegics, reducing insulin resistance in diabetics, increasing muscle mass in conditions of muscle wasting, articular deterioration aggravated by weight bearing and potentially certain forms of pulmonary edema (Cardus 1994).

**Concluding Remarks**
Astronauts born and developed in 1G will only maintain a level and the ability to return to 1G in reasonable health if they are provided with a means of maintaining throughout a mission, the 'memory' of gravity in all systems. Intermittent hypergravity, daily, all day, may make this possible. The objective would be to design the simplest possible onboard centrifuge that would be fun to ride, crew friendly, and simple to use several times a day .
This information is needed to enable the design of effective gravity prescriptions and provide the specific flexible artificial gravity devices that can make exploration possible. Furthermore, this information will finally make it possible to appreciate, as we do in plants, that humans rely on gravity for their physiological health on Earth.

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