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MICROGRAVITY AND ITS BEARING WITH SPACE FLIGHT-RELATED RESEARCH

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Abstract:

This study investigates the unique properties and applications of microgravity in the context of spaceflight research. Understanding and harnessing the behaviors of a microgravity environment opens the doors to long-term space travel and consequently, future missions to other planets within our solar system. More specifically, simulating and conducting experiments in microgravity environments helps us explore its effects on the various necessary tasks and behaviors that are carried out during spaceflight. The most immediate and pronounced effects of microgravity are on human physiology. Studies have shown that prolonged exposure to microgravity can result in a 20% decrease in muscle mass and a 5% decrease in bone mineral density. As research on these effects continue, astronauts will be better equipped to battle these unusual conditions in order to maintain a healthy and able body during spaceflight. In addition to its effects on the human body, microgravity environments provide promising ways to manufacture materials that would otherwise be too costly or difficult to create on Earth. Manufacturing materials of incredible strength and developing cables that can transmit information at unprecedented speeds are made possible in a microgravity environment. Not only does this paper summarize the currently known effects of microgravity, but it also explores the direct applications of microgravity research in past, present, and future space missions.

Methods:

Articles and previous studies analyzing the effects of microgravity on human physiology and in-space manufacturing were used to amalgamate information.

Table 1									
Updated list of ESA-sponsored bed rest campaigns since 2000.									
Name	Year	Place, subjects	PRE (d)	HDT (d)	POST (d)	Intervention	HDT angle		
LTBR 01-02	2001/2002	Toulouse, 25 males	15	90	15	1) Flywheel exercise 2) Bisphosphonate	-6°		
STBR 01-02	2001/2002	Cologne, 9 males, Cross-over	9	14	3	Caloric variations in nutrition, Amino acid infusion	-6°		
BBR	2003/2004	Berlin, 20 males	3	56	6	Vibration exercise	0°		
WISE	2005	Toulouse, 24 females	20	60	20	1) Combined resistive exercise, aerobic exercise, Lower Body Negative Pressure 2) Nutritional supplement	-6°		
BBR2-2	2007/2008	Berlin, 24 males	9	60	7	1) High-load resistive exercise (RE) 2) RE+ whole-body vibration	-6°		
BR-AG1	2010	Toulouse, 12 males Cross-over	5	5	5	1) Artificial gravity by daily short-arm centrifuge for: 30 min 2) Intermitent (x 5 min	-6°		
SAG	2010/2011	Cologne, 10 males Cross-over	5	5	5	1) Locomotion replacement training 2) Upright standing	-6°		
MEP	2011/2012	Cologne, 10 males Cross-over	7	21	6	Combined supplementation of 0.6 g whey protein (WFP)/kg body weight (BW) and 90 mmol potassium bicarbonate (KHCO3)	-6°		
MNX	2012/2013	Toulouse, 12 males Cross-over	7		6	1) Resistive Vibration Exercise (RVE) 2) RVE + Nutritional Supplement	-6°		
RSL	2015/2016	Cologne, 24 males	14	60	14	Reactive jump	-6°		
TBD	2017/2018	Toulouse, 20 males	14	60	14	Cocktail	-6°		

TBD, to be defined; d, duration (days) of the different bed rest phases (PRE, before; HDT, head-down tilt; POST, after HDBR). Cross-over: subjects repeated the study, first in the control group, then in the countermeasure one.

Figure 1: Above is a table summarizing the results of various experiments attempting to counteract the simulated biological effects of microgravity through nutritional and physical interventions (Demontis et al. 2017)

Introduction:

Microgravity is a phenomenon where the effects of gravity become imperceptible in an environment, thus creating a sense of weightlessness for anyone present. Currently, the most common microgravity environment that astronauts encounter is the International Space Station (ISS), which travels around Earth in a constant free fall. It is this constant free fall that creates the illusion of a gravity-less environment on the ISS.

Microgravity’s unusual effects on the human body force the body of astronauts to adapt to the novel environment. Many of these adaptations have proven to be dangerous to an astronaut’s health, and so an analysis of these effects would not only ensure the health and safety of astronauts in future space missions, but it would also accelerate the rehabilitation process for astronauts returning to Earth after prolonged exposure to microgravity.

Previous studies of microgravity have also revealed promising new ways to manufacture materials in space. Manufacturing in microgravity has proven to be useful in efficiently creating stronger and more unique materials in space that would otherwise be too costly to manufacture on Earth. A deeper exploration of these effects would revolution material science and eventually lead to the commercialization of space.

Figure 2: ISM phased technology roadmap (Prater, J. T., et al. 2016)

Figure 3: ZBLAN fibers pulled in Earth’s gravity (right) shows greater defects than the smoother fibers created in microgravity (NASA)

Discussion:

After reviewing multiple studies on the effects of microgravity, microgravity has significant effects on human physiology. Several experiments have been conducted demonstrating the effectiveness of various interventions designed to counteract the osteoporosis, muscular atrophy, and cardiovascular deconditioning associated with prolonged exposure to microgravity (Figure 1).

It is also clear that microgravity has bountiful applications in space manufacturing . The current focus of microgravity research in the manufacturing sector is 3D printing and its capabilities during spaceflight (Figure 2). One of the ways that manufacturing in microgravity has proven to be superior to on-Earth manufacturing is the success of developing ZBLAN fibers that have significantly less defects than their Earth manufactured counterparts. (Figure 3). These effects have unveiled novel manufacturing methods than can revolutionize the fiber optics industry on Earth and in other sectors in the manufacturing industry.

Conclusion:

Microgravity research provides valuable insight into how long-term spaceflight can be sustained in future missions where astronauts are exposed to microgravity for months and years at a time. Understanding microgravity’s effects on the formation of small celestial bodies can even help us learn more about the geological properties of planets in low gravity environments. This is especially helpful when analyzing geological formations on Mars and how it compares to those on Earth. The unique properties and applications of microgravity are far from being fully explored and understood, and as new discoveries in microgravity are made, we become one step closer to deep-space exploration.

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