

Effects of Microgravity on the Human Body and Stomatognathic System

Mikrogravitenin İnsan Vücudu ve Stomatognatik Sistem Üzerine Etkileri

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ABSTRACT

Microgravity, a condition that occurs in space with a significant decrease in gravity, leads to a variety of changes in the human body. Individuals involved in space missions are often reported to have reduced bone density and muscle tone due to the effect of microgravity. The effect of this condition on the stomatognathic system is characterized by an increase in stress in the temporomandibular joint (TME) region. It is crucial not to overlook symptoms such as pain, restricted mouth opening, and dysfunction. This review aims to highlight the effects of microgravity on the human body, with a specific focus on its impact on the stomatognathic system.

Keywords: *Microgravity, Aeronautic Dentistry, Stomatognathic System*

ÖZ

Uzayda yerçekiminin önemli ölçüde azaldığı bir durum olan mikro yerçekimi, insan vücudunda çeşitli değişikliklere yol açar. Uzay görevlerine katılan kişilerde, mikro yerçekiminin etkisiyle kemik yoğunluğu ve kas tonusunda azalma olduğu sıklıkla bildirilmektedir. Bu durumun stomatognatik sistem üzerindeki etkisi, temporomandibular eklem (TME) bölgesinde stresin artmasıyla karakterize edilir. Ağrı, ağız açılmasında kısıtlılık ve işlev bozukluğu gibi semptomları göz ardı etmemek çok önemlidir. Bu derleme, mikro yerçekiminin insan vücudu üzerindeki etkilerini, özellikle de stomatognatik sistem üzerindeki etkisine odaklanarak vurgulamayı amaçlamaktadır.

Anahtar Kelimeler: *Mikro yerçekimi, Havacılık Dış Hekimliği, Stomatognatik Sistem*

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INTRODUCTION

Space creates a number of stress factors for humans (microgravity and cosmic radiation) that are not present on earth.^{1,2} Various changes and biological reactions develop in cells in response to changing conditions.³ In a situation called mechanotransduction, the dynamics of fluid balance and the biochemical response system change as cells sense forces. This affects many systems in the body, the senses of movement and balance.⁴

Studies are ongoing on the definition of microgravity, which is a state experienced in environments where gravity is very low and is often referred to as zero gravity. There is a consensus that this definition is inaccurate, as it has been found that gravity in space does not completely disappear but is reduced to very low levels.^{5,6}

The effects of microgravity on space workers are evaluated through simulations such as microgravity bioreactor simulation, drop tower simulation and space flight experiments. Simulated microgravity can be generated using a single axis (2- or 3-dimensional clinorotation) or two independent axes (Random Positioning Machine (RPM)). Real microgravity environment is also provided by parabolic flights where short-term microgravity experiments can be performed, suborbital/sounding rockets that allow for longer duration experiments, and space stations where very long duration experiments are performed.^{7,8}

Depending on the duration of space travel, the process of preparing for space operations varies. For short-term trips, basic planning such as physical examinations and exercise capacity are required, while longer-term trips require more extensive medical examinations and laboratory tests. When preparing for long-term space travel, it is critical to anticipate the effects of environmental factors and identify strategies to reduce these effects.⁹

Medical examinations conducted before, during and in space have shown that microgravity negatively affects the human body and disrupts the functioning of physiological systems, and one of the most negatively affected systems is the skeletal system.¹⁰

The aim of this review is to explain the effects of microgravity on the human body and to draw attention to its effects on the stomatognathic system. It also addresses the risks to human health caused by the changing physical conditions that occur with space travel and strategies to reduce these risks.

Effects of Microgravity

The effects of microgravity on the human body are summarized in Figure 1 and discussed in detail on a system basis.

Effects on the Immune System

Long-term space travel can lead to immune system deterioration.⁹ Microgravity can reduce immunity, particularly by affecting the proliferation ability and function of B and T cells, monocytes and neutrophils.⁴

Down-regulation of genes encoding the anabolic immune system causes immune dysregulation.¹¹ This dysregulation can lead to reactivation of viruses and development of antibiotic resistance. As a result of these changes, defense ability may decrease or overreaction to stimuli may occur.^{3,12} It has also been reported that Mesenchymal Stromal Cells grown in microgravity may contribute to recovery in spinal cord injury.¹²

Effects on Respiratory System

Long-term space travelers generally have normal lung function. However, in some cases, small changes may occur, such as a decrease in expiratory reserve volume (ERV) in the standing posture. These changes may be attributed to reductions in circulating blood volume and may be reversed on return to Earth.⁹

Effects on the Skeletal System

Microgravity can lead to a decrease in bone density, followed by bone loss as a result of affecting various systems.¹³ Studies report a %5.4 decrease in lower limb bone density for periods exceeding 28 days.³ The decrease in bone density, which is similar to osteoporosis, is associated with a lack of mechanical loading on the bones and decreases in factors such as sex hormones.

A decrease in muscle tone was observed in the simulated environment.¹⁴ The decrease in muscle tone is caused by inactivation of motor units called reflectoric atonia.¹⁵

In addition to osteoporosis in microgravity, the decrease in sex hormones such as testosterone and estrogen also contribute to decreased bone density.¹² The lack of normal force loading on the muscles can cause them to shrink and lose strength.³ Microgravity has shown that women lose more lower extremity muscle than men in the first 4 months.¹⁶

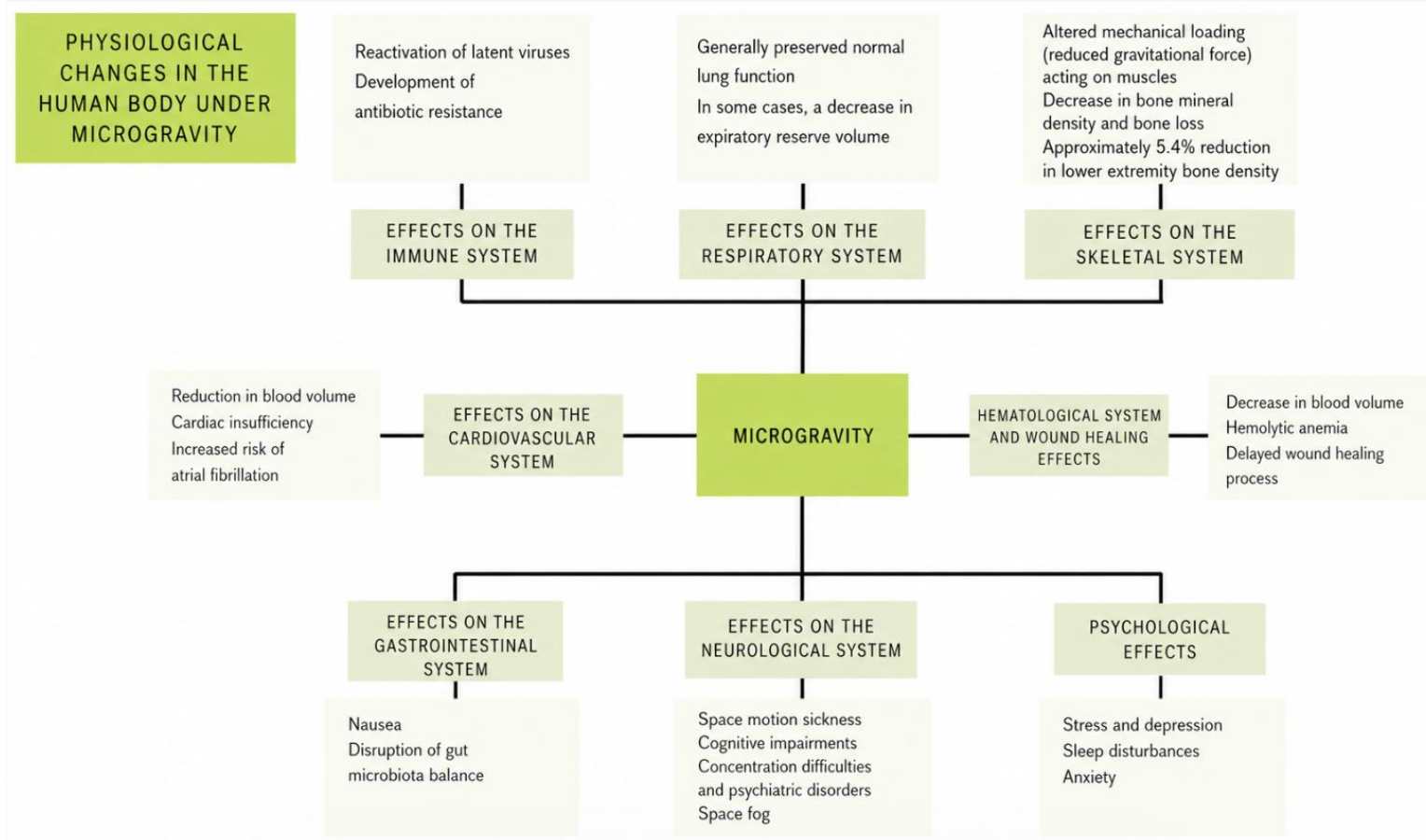


Figure 1: Effects of Microgravity on Human Physiological Systems

Effects on the Cardiovascular System

Microgravity conditions can affect blood circulation and therefore heart function.³ It can lead to reduced blood volume and heart failure. The risk of atrial fibrillation may increase in people involved in long-term travel and space studies.⁹

Effects on Hematologic System and Wound Healing

Reduced blood volume may be seen in short-term travel and hemolytic anemia may be seen in long-term travel.⁹ Affected circulation may slow the healing process.³ Microgravity also affects the proliferation and phenotype of vascular smooth muscle cells. It can cause hypertrophy of the vessel wall and hardening of the arteries.⁷

Effects on the Gastrointestinal System

Nausea and other gastrointestinal symptoms such as slowed digestion, are common during short-term travel. Long-term travelers may experience an imbalance in their gut microbiota.^{4,9}

Psychological Effects

Prolonged loneliness and limited range of motion can lead to stress and sleep disturbances in space travelers.³ Lack of social interaction can lead to mental health problems such as depression and anxiety.⁹ Increases in stress markers such as cortisol, alpha-amylase and beta-endorphins have been reported.^{4,17}

Effects on the Neurological System

Space travel can lead to changes in neurological functions. It can negatively affect the ability of nerve cells to synapse, the release and function of neurotransmitters, and the brain's learning mechanism.¹⁸ It can develop space motion sickness and cognitive impairments. It can cause problems such as impaired concentration, short-term memory loss and reduced ability to multitask.⁹

Cellular Changes

Oxidative stress, DNA damage and increased level

of cytokines and chemokines are seen in space conditions. This can accelerate the cellular aging process and increase the risk of diseases such as cancer.¹²

Changes in the position of organelles, regulation of charge distribution according to microgravity, changes in the physical interactions between the cell and the extracellular matrix can be observed.¹²

Effects on the Dermatological System

Skin problems are common during short-term space travel. However, these problems are usually mild and do not prevent space travelers from completing their space missions.¹² Microgravity causes degradation of collagen and extracellular matrix proteins.¹⁵ This has a similar effect to aging as it affects muscle tone.¹²

Aviation Dentistry

Aviation dentistry is defined as a specialty developed to protect the oral and dental health of people involved in space studies, to prevent and treat possible problems. This is a newly recognized dental specialty related to the application of dentistry to the aviation environment. Studies are ongoing to develop aviation dentistry.¹⁹

Stomatognathic System

The stomatognathic system consists of the oral cavity, jaw bones, teeth and the muscles and nerves that hold these structures together. Generalized bone loss and muscle atrophy also affect this system. When the stomatognathic system is affected, stress can occur in the temporomandibular joint (TMJ) region. This stress can cause pain, restriction of mouth opening and dysfunction.¹⁹

The stomatognathic system maintains the body's balance. It is important to protect the teeth of space workers from excessive G (gravitational) forces and prevent overloading of the TMJ muscles as a result.²⁰ The tone of the masticatory muscles can affect the whole body. In a study, an occlusal plate was applied to maintain the body balance of people involved in space studies. It was observed that the use of the plate provided more symmetrical contraction of the sternocleidomastoid muscles and reduced body imbalance.²¹

Studies on the effects of microgravity on the stomatognathic system are quite limited and the inferences made from the reviewed sources are summarized in Figure 2.

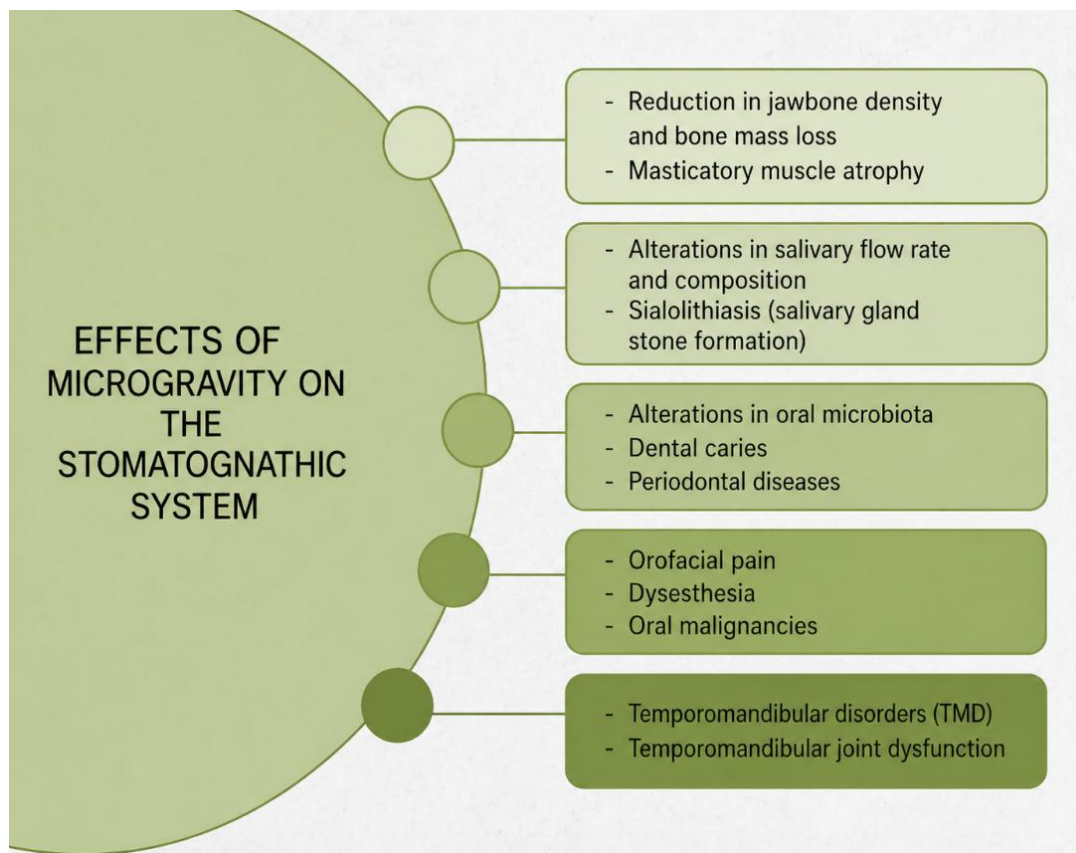


Figure 2: Effects of Microgravity on the Stomatognathic System

Oral Health in Space

Special toothpastes, brushes and treatment kits were used in space. Special anti-caries diets were prepared and oral health checks were carried out regularly. General evaluations of the people who will take part in space studies are made 6 months before they are sent to space and necessary treatments are carried out at least 3 months before they are sent to space. For conditions that develop during the time in space, diagnosis is made using photographs and descriptions of the person. Necessary equipment for pulp extirpation, temporary filling, pain control, and crown requirement are provided in the emergency package. Volumetric expansion caused by microgravity poses a threat to teeth requiring root canal treatment.²

Microgravity affects oral health by affecting saliva production, changing bacterial flora and altering oral hygiene.¹ These effects can manifest as tooth decay, various oral diseases, gum disease, temporomandibular joint dysfunction, sialoliths (salivary gland stones), pain and dysesthesia in the teeth and oral mucosa, masticatory muscle atrophy and oral cancer.²

Changes in Bone Structure

Important biological effects in space include bone loss and changes in the skeletal system. The activity of osteoblasts to build bone is reduced, leading to bone loss. This effect can cause osteoporosis in the jaw bones.²

Changes in Saliva Structure

Increased salivary flow rate and increased amounts of certain minerals (sodium, calcium, potassium, protein and phosphate) in the saliva structure can increase the formation of salivary stones.²

Microbial Changes

Bacteria are known to behave differently in zero gravity, sometimes exhibiting alarming levels of growth and tending to behave in ways not observed on Earth. Studies are ongoing to understand how this altered behavior is linked to the natural microbiome in the body

and oral cavity.²⁰

Oral microbial balance may change during space flights. Changes in the number of Streptococcus and other bacterial species have been observed. For example, an increase in the number of bacteria such as Bacteroides, Fusobacterium, Veillonella, S. Sanguinus, Neisseria and S. mutans has been observed. In addition, it is among the information obtained that gingivitis increased as a result of the decrease in salivary lysozyme, which provides defense for people working in space studies.²²

Oxidative Stress and Biofilm Formation

Studies have shown that microgravity causes oxidative stress by increasing reactive oxygen species.²³ In addition, the effect of microgravity on oxidative stress and biofilm formation ability of bacteria is one of the research topics. For example, changes in the sensitivity of S. mutans grown under microgravity to oxidative stress and differences in biofilm diversity were observed.²⁴

CONCLUSION

Microgravity causes physiological and psychological changes in people involved in space studies. These changes can be expressed as deterioration in the immune system, weakening in the musculoskeletal system, changes in the cardiovascular system, anemia, gastrointestinal problems. Effects such as depression and space fog are also observed during long flights. In addition, microgravity conditions are reported to have effects similar to aging at the cellular level. Therefore, strategies to reduce the health risks of space travel are important.

Microgravitation conditions can cause a variety of adverse effects on the oral cavity and teeth. Examples of these effects include gingivitis, caries, bone loss, pain in the teeth and mucous membranes, and oral cancer. Understanding, preventing and treating these effects is critical for long-term space missions. Further research in this area is necessary to understand and minimize the effects of long missions in space on human health.

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