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Vitamin D in Space

Amir Khoshvaghti

Neil Armstrong stepped on the Moon and said:

“That’s one small step for [a] man, one giant leap for mankind.” [1]

However, it was better to say:

“That’s one giant step for [a] man, one small leap for mankind.”

Abstract

Mankind has explored space since many years ago for distinct purposes. The space environment has its special features including microgravity (weightlessness), radiation, vacuum, and extreme temperature. It is fascinating to hear space traveling or even living on another planet, but it may cause dramatic changes in the human body. The skeleton has the primary role for the human body on the Earth and also in space. Osteoporosis is the principal feature in spaceflights occurring sooner or later. It will pose health risks. The aging of the population is the cause for osteoporosis to be more prevalent in the future. It seems that aging will happen sooner in space for human beings that are accustomed to living on the Earth. A complex of all reported changes that would occur in space, the picture of a closely resembling aged man emerges. Vitamin D can be synthesized and acts as a hormone. Its receptors are evident in more than 30 human tissues. Vitamin D has positive effects on the skeleton and other systems of the body in many regards. Multiple actions have been claimed for vitamin D (real or false), many aspects of which are not fully understood. The issue applies more about the vitamin and space, which has been tried to describe in this chapter.

Keywords: vitamin D, microgravity, spaceflight, bone loss, health risks

1. Introduction

The humankind had long been thinking and desiring to separate from the Earth. He lived on the Earth but considered it as a prison. Separating from the ground and climbing up for reaching the blue and bright sky were a kind of evolution and progression for a man’s dreams. One of the reasons for this thought was the natural curiosity of human being, along with other reasons including scientific progress, financial outcome, and so on.

2. The desire to fly

The humankind in this field even turned to the imagination. He always dreamed about the angels, carrying two flights on the back of them. He made stories and myths like Icarus about flying and releasing to the sky.

Problems gradually showed up themselves. The first problem was the separation from the Earth. Every time that he jumped up, he fell on the ground again, even from towers. Each time he tried to get higher, the gravity did not allow him to move away from the Earth, and he was returned. He then realized that he had to use a special force to win over and dominate the gravity. Little by little he took more serious actions, designed to make practical models of flight. The Chinese invented a rocket, which had the necessary power for overcoming the gravity. Leonardo da Vinci was a brilliant scientist, designer, and inventor of the field in the fifteenth century.

A Journey through Space was written by William Leitch in 1861. He was a Scottish astronomer and mathematician. He announced the theory of traveling to space with rockets [2].

Russian scientist Konstantin Eduardovich Tsiolkovsky (1857–1935) wrote about going to space using special devices in 1903 (the same year as the Wright brothers' flight) [2].

At last, the man could be separated from the Earth to fly in the sky. The German Otto Lilienthal (1848–1896) studied flying scientifically and had 200 gliding flights in the second half of the nineteenth century [3]. The Wright brothers (Orville, 1871–1948 and Wilbur, 1867–1912) as American aviation pioneers made the first piloted flights in 1903 [4]. Now it was the time to provide suitable facilities to fly longer or to reach higher.

The past Soviet Union (current Russia) sent the first human (Yuri Gagarin, 1934–1968) to the orbit on April 12, 1961. They had sent animals to space before this exciting experiment. The first animal was a Russian dog called Laika 1 month after the launch of Sputnik on November 3, 1957. Russians sent six dogs to the orbit from 1960 to 1961. A chimpanzee called Enos was the first animal sent to space by the USA on November 29, 1961. John Glenn was the first American astronaut in space on February 20, 1962 [5].

Since the flight of Yuri Gagarin, more than 500 people have flown to the orbit of the Earth. Even a few have advanced beyond the orbit, the Moon.

After starting to fly, humans realized that there would be more problems at higher altitudes. One problem became evident when he went a bit higher. The atmosphere became thinner and thinner, so he was forced to struggle for breathing. Then he had to make the flight device so sealed that it could regulate the air inside to have no respiratory problems or other problems due to lack of oxygen and hypoxia. He designed and made special balloons for flying at high altitudes (rediscovery of hot air balloon by the Montgolfier brothers) [6].

At the same time, scientists noticed that everything could not be experienced in the sky (or space) and during flight. Unfortunately, some experiences led to fall, collapse, and death. The experiments were commenced on the Earth by simulating different models (from cells to animals and finally up to human beings).

At that time, the new problems appeared one after another. The man noticed that by going farther from the surface of the Earth, there would be less gravity. Somewhat farther, he almost did not feel any gravity. Weightlessness had occurred.

Other problems were included as exposure to radiation and its resulting discomforts. So, on the one hand, the man had to think about the ways continuing to fly and perform missions successfully and, on the other hand, not to confront any physical problem himself, doing his best with maximum efficiency and power.

The efficient hypothesis was that the astronaut should be able to maintain his abilities in long-term flights up to the end and to act effectively meanwhile. In recent decades, 6-month missions have been carried out regularly in Russia's Salyut, the Mir station, and the International Space Station (ISS), respectively [7]. In addition to such missions, various studies have been done on human body changes

in space travels and missions, in order to grasp the practical concept of adaptive conditions, although this understanding is still incomplete.

The space environment and space travel have particular challenges and dangers within itself. Regular and planned efforts have been made to understand these changes and alterations in order to allow protection and countermeasures development and implementation against harmful effects. The field of optimization of human performance in every respect is provided. In this context, the following should be considered:

1. Changes in acceleration at two steps:
 - a. When the spacecraft rises from the ground
 - b. At landing on the surface of other planets or upon returning to the Earth (from full extent until its complete absence during weightlessness)
2. Different atmosphere compositions (containing variable pressures and different amounts of oxygen)
3. Other features such as radiation (including ionizing radiation)

It is nearly two decades since the establishment of the first component of ISS in 1998. It is believed to operate until 2028. Several long-term missions have been planned to accommodate astronauts. The main goal is to get the ultimate readiness for exploratory missions beyond the Earth's orbit [8].

The American and Russian space programs were ambitious and, at the same time, scientific and full of research. Their main goal was the long-term deployment of systems and platforms in the Earth's orbit to make orbit stations. They intended to send astronauts to these platforms and stations for long-duration missions. Astronauts had to stay and work at space stations for a long time so that reliable research could be done in this area. Scientists achieved much more about physiological and pathological changes in the space. The complete adaptation of the human body to weightlessness would take several weeks, which could not be provided by previous spaceships [9]. Also, many experiments and researches were possible to be done in this case.

Sometimes later, the scientific thoughts looked farther, beyond the Earth's orbit. Terrestrial missions refer to those space missions that are far from the orbit, where there is no longer any protective effect of the atmosphere and the electromagnetic fields, and they will not affect the spacecraft longer. The American Apollo programs are among these series of missions that consisted of nine missions and flights to the Moon. In six missions, two astronauts landed on the surface of the Moon. Each trip lasted between 8 and 12 days, which spent 3 days traveling from the Earth to the Moon. An essential point about Apollo's trip was the ability of humans to perform physical activities in an environment with gravity much lower than on the Earth's surface, equivalent to one-sixth. It is worthy to mention that gravitational force on the surface of Mars is twice that of the Moon and a third of the Earth [10].

With the advent of space exploration by Vostok 1 and Yuri Alekseyevich Gagarin's journey in 1961, the man has been exposed to space-related problems including microgravity [2]. The cells, tissues, systems, and the human body as a whole are generally exposed to different physiology other than the physiology that dominates our planet and undergoes alterations. Of course, the musculoskeletal system is among those systems that have the most changes and problems, especially in the face of microgravity, such as bone mineral density decrease and muscle atrophy [11].

Microgravity and cosmic radiation are two important dilemmas that exist in the space environment affecting human health and endangering it. They significantly affect the future of long-term space travels and would limit them [12].

In a long space trip, including a trip to Mars, astronauts are exposed to large amounts of radiation which is much higher than the magnitude permitted by the NASA's system of protection [13].

3. History

In the twentieth century, spaceflight became real. The modern space exploration era begins in 1961 with Vostok 1 and Yuri Gagarin's journey because human travel to space is the most important event in this regard [2] although other measures, including the first orbital spaceflight (1957) and release of animals to space, were done earlier [5].

Nowadays in medicine and biology, Yuri Gagarin is a gene in *Drosophila* which has codes for three proteins [14].

In the USA, the National Advisory Committee for Aeronautics (NACA) became NASA on 1958 [1].

The first human who landed and walked on the Moon on July 20, 1969, was Neil Armstrong (1930–2012, American astronaut and commander of the Apollo 11). His colleagues were Michael Collins and Edwin Aldrin [1].

The deployment of ISS in the low Earth orbit (LEO) was carried out to rotate the human body around the Earth at the height of about 400 km; then another great mission was performed. Ninety percent of gravity at ground level will be endured by astronauts in LEO [9].

So far, about 90 astronauts have arrived at the ISS, with an average length of stay of about 6 months (6). The Apollo program included human missions and spaceflights above LEO. The program ended in 1972. During this program, 12 astronauts traveled to the Moon, which lasted for a few days [10].

The Chinese are trying hard to build their space station which will be built around 2020 [11].

4. Spaceflights, Earth, Mars, and again Earth

Astronauts are preparing to travel to Mars now. Two and a half years are considered for this mission, part of it for spaceflight and the remaining for settlement and scheduled activities on the planet [15].

They are exposed to weightlessness in their 6-month course, which seems to make them physically very disable and inefficient at the end of the flight [7].

Most astronauts will encounter problems in spatial orientation and balance during the first few days after landing. They will be at risk for fractures and muscle tears during recovery period [9].

If the astronauts reach Mars with a weak and inadequate physical condition, having no solution to perform their basic tasks, the mission will face serious risks and will almost fail. Astronauts will endanger greater risks by sensory-motor impairment during spaceship control, off-vessel operations, or remote-controlled tasks. As long as the problems caused by weightlessness were not solved successfully, it is not wise to consider the long-term human journeys and missions like going to Mars [9].

Nowadays, human exploration missions to the Moon or Mars are considered as the next logical steps in the space era. In some cases, even human dispatch and

migration, and colonization in other worlds, have also been announced. Almost all major national and international organizations in the world, as well as private investors and business plans, are currently developing roadmaps and related technologies to bring a healthy human to other planets of the solar system. Gradually, it seems that mankind is going to imagine about frequent and extended space trips, so that interplanetary traveling is equivalent to the concept of intercontinental flights. The human spaceflight perspective looks at the following to achieve in a short period:

- A significant number of travelers
- Longer flights and farther distances
- Sustainable deployment of humans to other planets as well as colonization

Many different challenges would be encountered that scientists and also politicians should overcome [9].

Most of the medical challenges that were faced during humanitarian missions and related steps were mainly due to radiation and effects of microgravity (or hypogravity) as well as psychological issues [8]. In future exploratory missions for the Moon and Mars, the crew will be exposed to problems of the permanent base establishment on the planet, long-duration flights and missions, radiation intensity, microgravity, and the different impressions of constraints and isolation. It poses several health issues that may be a limiting factor during these missions. The health and performance of the crew should be ensured during journeys on the transfer and discovery of the planet's surface, external vehicle activities, and after returning to the Earth. In particular, the mission to Mars includes more challenges: the planet's distance, travel time (at least 500 days), and the impossibility of suspending the missions that necessitates an entirely stable mission. There could not be any support from the Earth in the major health problem or technical one [9].

5. Types of simulation of space travel

1. Human:

- a. Bed rest (prolonged bed rest protocols and head-down tilt experiments, about 6°)

Head tilt is the most used space analog in scientific researches. The head is tilted down (-6° almost in all cases) during lying in a bed for different periods according to the study. There would be a cephalic fluid shift, immobilization, and isolation in this kind of modeling [16].

- b. Separation and isolation environments (similar to studies conducted in Antarctica or research that people live in and operate in specific environments and chambers, such as those conducted by volunteers traveling to Mars) [17]
- c. Parabolic flight: although weightlessness will be executed only for some seconds [18].

An airplane has alternative flies so that there would be three phases (normal gravity, hypergravity, and microgravity) in each period. Microgravity lasts about

20 seconds. Parabolic flight is the only simulation model that the person feels real microgravity. The airplane might fly until 30 periods maximally in a flight [18].

2. Computer simulation (especially in musculoskeletal biomechanics):

The data which are gathered or extracted from spaceflight and other experiments such as parabolic flights have been documented to validate the results of simulations [19].

3. Animal: Particularly about the points that could not be implemented even by human studies, such as:

- a. Bone and muscle radiation
- b. Detection of genetic effects on osteoporosis and muscle atrophy
- c. To identify the process of bone fracture restoration in the space travel environment (i.e., weightlessness and immune system alterations)

The main reason for performing animal models and simulation is that spaceflights are rare and expensive [20].

Several studies have been performed using tail suspension model, hind-limb suspension model, and so on (especially in rodents such as rat and mouse) [21, 22].

4. Cell [23]:

- a. Rotating wall vessel (a kind of two-dimensional clinostat)
- b. Random positioning machine (a kind of three-dimensional clinostat)
- c. Other types of clinostats

Scientists use ground-based models because of two reasons [24]:

- They have more control over the research situation.
- The cost would be much less.

Parabolic flight is such an analog. An airplane repeats a particular flight, so there would be a few seconds of free fall (weightlessness or no gravity) in each period.

Importance of human and animal simulations is stated as [5]:

- To study on high sample numbers
- Understanding human sexual differences (effectiveness of interaction)
- Reaction and interaction of different countermeasures (including nutrition, exercise, drugs, sleep, and others)

The reasons for not replacing cellular simulators instead of real flights are as the following [23]:

Cell simulators are important regarding creating insight into the suitability of future space missions, but it can be argued that these devices may still not replace the experiences of space travel. In this regard, two reasons can be counted:

1. Space travel has its complexities and complications since microgravity is not considered as the unique problem alone, but hypergravity, radiation, and vibration are also entangled.
2. The rotation kinetics of this simulator may cause fluid movement and shake in the chamber, which adds extra force to the cells present in the medium.

Therefore, it is necessary to consider that the results of these devices and techniques should be confirmed with the experiences in real microgravity.

6. The effects of space and its physiology on the human body

Astronauts are healthy individuals who will pass many courses to be well trained and finally highly selected. They should encounter different physiology until accommodation to pathophysiological alterations as soon as possible. Space medicine has some similarities (hypoxia, dysbarism, thermal support, acceleration, and response to high altitudes) with both aviation medicine and diving medicine [9]. These branches of medicine are taught separately, but there are aerospace medicine residency programs in a few countries (aviation medicine plus space medicine). There is only one combined aerospace and subaquatic medicine residency course and faculty in Iran.

Living and working on the Earth differ with space as mentioned earlier. Standing or sitting is the ideal position for doing the tasks and responsibilities. Gravity direction is perpendicular to the surface of our planet, so the body fluids are pulled down. The same occurs to our bones and muscles. The following paragraphs show the alterations of the human body during spaceflights briefly.

Some changes due to of microgravity exposure would become evident after a few days (i.e., motion sickness), some after weeks (i.e., cardiovascular deconditioning), and some even after months (i.e., osteoporosis and muscular atrophy) [9].

6.1 Immune system

Immune problems that have been identified and reported during spaceflights are:

- Alteration in adaptive immunity regulation
- Disordered interaction between adaptive and innate immunity
- Changes in the distribution of peripheral leukocytes
- Decrease in function of some leukocyte types
- Change in cytokine profiles
- More infectious disease incidence

- More allergic symptoms (even sometimes prolonged integumentary hypersensitivity reactions) [25]
- Weak immune reactions
- Possibility of increasing opportunistic infections and immunity disorders
- Increase in virulence of microorganisms [26]
- Hindering of thymopoiesis significantly [27]
- More latent viral reactivation [28]

There are more reports about immune system alterations [25, 26, 29], but some authors have not reported significant changes [30].

6.2 Muscular system

The most frequent change is atrophy of skeletal muscles. Alterations are described as:

- Atrophy and loss of function in lower limb muscles (especially the triceps muscle) [31]
- Decrease in performance of lower extremities muscles [32]
- Atrophy of muscle due to stem cell pool decrease [33]
- Spinal deconditioning (including atrophy of the paraspinal muscle group, reduction in curvatures of the spine) [34, 35]
- More damage in plantar flexors than extensors due to a decrease of fiber size and protein synthesis [9]
- Reduction of volume and strength in lower limb muscles [36]
- Significant loss in total body nitrogen and muscle volume in the Mir station [37]
- Muscle atrophy greater than 20 days of bed rest [38]

6.3 Cardiovascular system

These changes have been observed:

- Alterations in shape and mass of the heart, cardiac function changes, and arrhythmias [39]
- Redistribution of venous blood volume [40]
- Cephalad fluid shift, not any change in heart rate, a decrease in parasympathetic activity, an increase in output and stroke volume, and no change in sympathetic nerve activity [41]
- Loss of arterial pressure gradient [9]

- Changes in venous function [42]
- More sensitive to space radiation (opposite to previous studies) [12]

The heart does not work against gravity, so it has less work (with associated advantages and disadvantages) [9].

6.4 Respiratory system

Different results have been published by studies, so the comparison would not be easy due to the environmental bias and the variability of experimental protocols [9].

6.5 Blood

- Spaceflight anemia (reported frequently) [43, 44]
- Sustained increase of RBC and platelet [45]

6.6 Central nervous system (CNS)

Currently, there is little known about CNS alterations in space [46, 47]. The following structures are more affected than other parts of the CNS: cerebellar, sensorimotor, and vestibular brain regions [48].

6.7 Autonomic nervous system

Orthostatic stress has been reported, but its severity is less than on the Earth [49].

6.8 Sleep

Sleep problem is a common issue in space. It may affect the health of astronauts, so the safety of the mission would be endangered. Six causes for sleep alterations might be (1) factors related to cabin environment, (2) schedule adjustment, (3) impaired sleep discipline, (4) disordered circadian rhythm, (5) unreasonable work arrangement, and (6) mental and/or physical factors [50].

6.9 Eye

Spaceflight-associated neuro-ocular syndrome has been reported which is associated with optic disk edema (unilateral and bilateral), flattening of the eyeball, folds of choroid and retina, hyperopic refractive error shifts, and nerve fiber layer infarcts [51].

6.10 Skeletal system

Most changes occur in the skeletal system. Osteoporosis can be a major obstacle to the actions and activities of astronauts, especially in long-term missions and/or traveling to other planets [52].

Skeletal changes in spaceflights seem to be the most important alterations because they may limit or even stop a space program [53]. Rate of monthly 1–2% bone loss has been postulated during spaceflights [52] and 0.5–1.5% by some other investigators [54]. It could be up to 15%. Returning to normal values after landing

on the Earth is much slower, maybe only 6% annually [55]. Vico et al. did not observe recovery at skeletal sites the year after return from ISS in 2017 [56]. In 2010, Dana et al. stated prolonged consequences of bone loss even after 2.5 years following a stay on ISS [57].

It has been shown that bones of the lower extremities become more osteoporotic in comparison to other parts of the body. Skull bones are less affected, and even some report increased density of the skull. Then we may assume the most critical factor of osteoporosis to be unloading [16].

Several articles have shown the skeletal system and its physiology alterations due to spaceflight [54, 56–60]. LeBlanc et al. reported a 5% decrease of bone mineral density was observed in 92% of 60 American and Russian astronauts during long-term flights lasting 4–6.5 months [61]. The review by LeBlanc et al. showed that weight-bearing bones had more bone mineral loss [62]. The results of Skylab were repeated in the Soyuz and Mir missions [9]. 1,25-Vitamin D and its precursor reduced significantly in the Mir 18 mission [9]. Lang et al. claimed their data shows that full recovery of bone density was not complete even after 1 year [59]. Experiments conducted in the Mir station demonstrated 13% of osteoporosis in the pelvis which had the most significant range of bone loss in comparison with other parts of the skeleton [37].

7. Vitamin D

In missions and space travels, the health of the astronauts and, consequently, its maintenance are essential, and it would be vital in some cases and situations. Proper nutrition will positively affect human health; vitamins such as vitamin D have important roles too.

Leach and Rambaut's research on Skylab 4, published in 1977, showed that the amount of vitamin D was lower in astronauts, even with supplementation of 500 units per day. Their mission was 84 days long, but such results were not observed for previous Skylab's short-term missions (28 and 59 days) [63].

The studies on astronauts of the Mir space station showed that the amount of vitamin D had dropped. The reasons were considered as the following [52]:

- Consumption of low vitamin
- Lack of exposure to ultraviolet radiation

In 2001, Smith and colleagues conducted a study on nutrition status assessment in 2 isolated environments (2 missions 60 and 91 days long, 4 participants, on the Earth) and a 4-month residence of two astronauts at the Mir station. They found that the amount of vitamin D was 32–36% of the average value [64].

Smith et al. published the results of nutritional status of 11 astronauts with long-term missions on ISS (128–195 days, 2000–2004). The program contained 10 µg/d of supplementary vitamin D; 10 micrograms of cholecalciferol was in each supplement. A significant decrease (25%) was observed on 25-hydroxycholecalciferol after the mission, and bone markers showed increased resorption [63].

The report indicates weekly consumption of 5.7 ± 4.0 supplementary vitamin D per (and mean of 3.5 ± 2.9 supplementary multivitamins) [63]. It does not seem to be a sufficient amount of vitamin D for compensation.

Following the launch of the ISS, the order for supplementing vitamin D was issued to astronauts. Meanwhile, the twenty-first century had come. In the first

decade of this century, vitamin D was considered by anyone, and a wave of research and reports began. Everywhere we heard and read about this vitamin, from newspapers, magazines, radios, and TVs. The Internet was also overwhelming. Are considerable number of articles and papers, and surprising notes showing that vitamin D is of tremendous importance and everything from cancer and a variety of serious diseases and dangers to a variety of even chronic infections such as tuberculosis would be impacted. The results of the mentioned wave were expanded from the Earth to the sky and space. Fortunately, this was a positive aspect of the case, so the daily dosage of vitamin D increased from 400 to 800 units for astronauts on ISS [65].

The research published by Smith et al. in 2012 was based on 13 astronauts (9 males and 4 females, between 2006 and 2009, length of mission as a long one between 4 and 6 months). It was the first study of this type that showed the mineral density of bones, and risk of osteoporosis would be reduced in long-term space mission by severe exercise and adequate feeding (good energy, plus 800 units of vitamin D per day, which was twice the amount of vitamin D prescribed in previous missions). Of course, the results were achieved by bone remodeling [66] more than by bone resorption reduction. Blood and urine specimens were prepared before, during, and after space travel, but densitometry was performed before and after the trip. Their findings can help ensure that vitamin D is sufficient to live in an environment that does not have any exposure to ultraviolet radiation and with limited food available (as the source of vitamins).

7.1 Vitamin D and the positive point

Vitamin D is easy to use and available. Its cost is not so much, and it may be prescribed as an efficient strategy in hindrance and/or prevention of space-induced changes (particularly in bone) [21].

7.2 Vitamin D and the negative point

An important subject that should be considered is vitamin D does not have an infinite capacity for preventing osteoporosis (cellular process) [22].

7.3 Vitamin D story continued

In another research, our team measured the bone mineral density of 14 rats' femur and demonstrated morphologic changes for the contralateral femur after supplemental calcium/vitamin D. The bone mineral density and bone mineral content had a significant increase in the experiment group. The outer cortical bone thickness was also higher [21].

Astronauts should be healthy and able to maintain their health in order to be capable of performing their tasks as the best as possible. It should be implemented during and even after space travel (either landing on Mars or returning to the Earth). In this case, nutrition is of particular importance for the body as a whole and cellular processes. The food is packaged and ready for astronauts, which should be of good quality and, at the same time, meet the requirements of scientific references [67].

Cooper et al. published their research results on astronauts' food quality assessment in 2017 [67]. They examined 24 micronutrients including vitamin D in 109 food packages for 3 years and determined the amount of vitamin D at the beginning of the study, 1 and 3 years later. It turned out that vitamin D is not even adequate at

the beginning of the study compared to standard food tables! It was less than 50% of the required amount!

Please read the last paragraph again. It is amazing. Astronauts are selected and qualified persons after many tests and exams. It is rational that their food should be as suitable as possible and highly selected. The scientists had noticed the decrease of vitamin D in several studies, so they proposed the causes and solutions, but it seems that nobody noticed and tested the real amount of vitamin in foods (of course before Cooper et al. [67]). Modern life has changed our lifestyle; we become obese more and more, limited body activities and exercises, not going out of the buildings, using more sunscreens, maybe more makeups (especially in third world countries), covering all of the body (religious or national belief). Sunlight does not touch our body and skin. Vitamin D would not be produced. Then we should rely on the foodstuff, but they do not have sufficient vitamin D; a great disaster begins! It is so simple!

Therefore, the first solution would be the necessity of providing vitamin supplement for astronauts [67]. Since 2006, it has been announced that vitamin D supplementation would be part of the regular nutrition program in spaceflights [65].

Other solutions to this problem include:

- The use of vitamin D-rich or fortified foods in the diet of astronauts
- Specific/specialized techniques for storage and maintaining adequate amounts of vitamin D in foods during travel

In 2016, Wotring examined nine drugs which had been returned from ISS for the sake of their chemical power and degradation percentage. Their maintenance under the unusual situation in space travel may be associated with increased drug decomposition. Until now, the drugs are replaced by new ones before the expiration date. It is unlikely to be possible to replace expired drugs on a long journey such as to Mars. Wotring failed to provide a complete guide to this issue because there was no control sample on the Earth and proposed more studies should be carried out [68].

Although prescribing vitamin D supplements can be proposed as a nutritional countermeasure, supplements may also degrade and lose their effect. In this regard, comprehensive research should be provided [67].

Zwart and colleagues published their research results in 2009, considering that maintaining and supplying food in spaceships are vital and essential to the success of the mission and health of the astronauts. Based upon past studies conducted on the Earth, they announced that long-term storage of vitamins or exposure to radiation might alter some of these, so that their intake does not affect, or even dangerous and harmful. They sent four identical kits containing foods and vitamins (including vitamin D supplements) to ISS in 2006. They also kept a control group (similar packages) at ground level. The experiments were carried out on four occasions (on the days 13th, 353rd, 596th, and 880th). The amount of vitamin remaining after 596 days changed due to the length of storage time in most foods, but the final results showed that there was no difference between space travels and the Earth's surface [69].

Some studies (including Smith et al.) have suggested that the amount of vitamin D in long-term space travel would change, with possible causes as [70]:

1. Metabolism in various stages of vitamin D metabolism:

- a. Absorption

b. Consumption

c. Excretion

2. Food decomposition due to:

a. Time spent

b. Other unknown causes

Smith et al. have referred to vitamin D reduction in 3- to 6-month space travel (with unknown mechanisms) in three different studies (published in 1999 and 2 papers in 2005). This was while the spaceship crew had consumed the supplement too. No mechanism is known for such a reduction, although two factors can be considered alone or in combination [69].

- Long-term food storage
- Ionizing radiation

These two factors can disrupt the feeding of astronauts through the following routes [70]:

- Food decomposition
- Reduced bioavailability
- Food oxidation and the emergence of inappropriate odors

Another point to note is the effect of radiation on vitamins. Vitamins are considered to be human-protecting sources that do not have any substitute. If we consider vitamins to be isolated from food, then radiation would have little effect on them, because they are considered as small molecules. However, if the radiation hits the vitamins inside the food (where molecules of water and lipids are around them), there would be radicals that might affect vitamins negatively [69].

Better than any conclusion, please go straight to the summary and find it there.

8. Summary

Human chose spaceflights many years ago. The space environment has its distinct physiology which is different from the Earth. Dramatic changes would occur in the human body totally and in the skeletal system as a part. There would be no trivial sun or UV exposure in spaceships; so everything is ready for the advent of osteoporosis. In such situations, vitamin D had come to the scene, to corporate positive effects in the skeleton and other body systems. Studies have shown some promising results, but as revealed earlier, the main concern and problem would be the amount of vitamin D in prepared foods for astronauts (lesser than expected and standard values). It seems that distinguished scientists have noticed the subject and have tried some solutions, maybe a process, suitable even on the Earth.

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Conflict of interest


There is no conflict of interest.

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