Physiological changes in the human body in the microgravity environment

Alterações fisiológicas no corpo humano no ambiente de microgravidade

Bruno Leonardo Carvalho Peixoto

ABSTRACT

Introduction: Human beings have been evolving exponentially, however, the facets of this evolution occur in independent times despite being intrinsically linked, such as the technological evolution that evolved us in such a way that human biological evolution itself has become irrelevant to the standard of modern human life, the human being has been developing technologically very quickly, allowing us to idealize interplanetary travel, exploration of mineral resources from asteroids that pass close to Earth orbit, even the formation of other planets. Therefore, in this context, it is possible to identify a pattern that shows a greater need for human beings to undertake space travel more frequently and for longer, which also implies greater exposure to the risks and harm that this medium can offer. Objective: To show regulatory changes in the human body resulting from long exposure to the microgravity environment. Methods: The related study is a literature review of the systematic review type, where the following platforms were used as a search base: SciELO; LILACS; PubMED; Medline; ScienceDirect; Cochrane Controlled Trials Database; New England Journal of Medicine; ESSENTIAL; Circulation and Springer. Results: 18 relevant studies were found through the SciELO databases; LILACS; PubMED; Medline; ScienceDirect; Cochrane Controlled Trials Database; New England Journal of Medicine; ESSENTIAL; Circulation and Springer. Among these, 13 studies were eligible, since all studies addressed at least one of the inclusion criteria. Conclusion: It is concluded that there is a shortage of studies on this subject, due to a series of difficulties, from its applicability, collection, cost and control. However, the few studies found are unanimous regarding regulatory changes in the human body and how these directly impact their health.

Keywords: Weightlessness, Astronaut, Microgravity, Space flight, Biological volution, Natural selection.

1 INTRODUCTION

Humans have been evolving exponentially, however, facets of this evolution occur at independent times despite being intrinsically linked, such as technological evolution that has allowed us to evolve in such a way that human biological evolution itself has become irrelevant to the standard of living of modern humans, some altors believe in a recent stagnation of the human biological evolutionary process: "It has been argued that human evolution has stopped because humans now adapt to their environment through cultural evolution rather than biological evolution" (ALAN, 2010, p.1).

According to Gould expert Stephen Jay: "There has been no biological change in humans in 40,000 or 50,000 years. Everything we call culture and civilization, we built with the same body and brain."

All of the approximately 3.5 to 4 million years of the human evolutionary process, according to the neo-Darwinian model, took place on land, and therefore occurred in a way that obeyed the laws of terrestrial physics.

> The Theory of Evolution states that it is the environment, through natural selection, that determines the importance of the individual's characteristic or its variations, and the organisms best adapted to this environment have a greater chance of survival, leaving a greater number of descendants. The best adapted organisms are therefore selected by the environment and, thus, over the generations the action of natural selection maintains or improves the degree of adaptation of organisms, fixing their characteristics in the environment. (FERNANDES, 2018, p. 1).

That is, the human being might not be able to adapt and evolve in an environment where the evolutionary conditions differ from those imposed on us on earth (nutrition, climate, gravity), which leads us to an impasse, the human being has been developing technologically very quickly, allowing us to idealize interplanetary travel, exploitation of mineral resources from asteroids that pass close to Earth's orbit even the formation of other planets, all of these supported by a scientific theoretical basis. Therefore it is possible to identify a pattern that says about a greater need of the human being to carry out space travel more frequently and for a longer time, which also implies a greater exposure to the risks and harms that this medium can offer.

It is already possible to identify the damage to the human body when exposed to the microgravity environment and how these changes progress if exposure continues, among the changes that occur in the human body associated with the microgravity environment we can mention the following systems: cardiovascular, bone, muscle, vestibular, optical, immunological and circulatory.

The rehabilitation of these patients after long exposure to such an inhospitable environment can be slow and requires the attention of the entire multidisciplinary health team, with the important role of physiotherapeutic rehabilitation in the process to restore the basic functions of proprioception, gait, balance and strength that are usually altered in the face of post-exposure normogravity, in addition to reconditioning for new trips.

2 MICROGRAVITY AND ITS SYSTEMIC EFFECTS

Microgravity consists of the total or almost total absence of body weight, it can also be reproduced in underwater tests on earth making the process of studying its effects on humans cheaper and more reproducible, practically every context of life that we understand today has evolved under the effects of terrestrial gravity and with recent technological advances, we started to expose human physiology more frequently to the changes caused by the microgravity environment.

It is important to emphasize that although this study deals with changes in human physiology, the changes found in other animals or more complex organisms were very similar to that of humans to the point of being compared, it is understood that other animals would also be susceptible to changes in microgravity, as they also evolved under the effects of terrestrial normogravity, except for some types of fungi that appeared to reproduce and spread more easily in the environment of space stations (SUGITA, 2016, apud GILKE, 2019, p.2).

2.1 CARDIOVASCULAR AND CIRCULATORY SYSTEM

There are a number of complications associated with the cardiac system, hydrostatic changes and poor intake of essential components for the correct functioning of cardiovascular structures during long-duration space flight.

> In microgravity, the heart and blood vessels are relieved of the hydrostatic forces exerted on them by the blood. The heart becomes round, potentially altering its pumping action. The blood is no longer drawn to the feet. The blood pumped by the heart "floats" forward and stays in the head and upper torso. This causes a redistribution of blood and interstitial fluid towards the upper torso altering the physical shape of the astronaut's body causing a swollen face, engorged neck veins, an enlarged chest and reduced leg volume. (KANDARPA, 2019, p.2).

"During a study of 12 astronauts on 6 missions, it was found that in space flight the astronauts' hearts showed reduced rates, however, it is suggested that these reductions are associated with the cardiovascular system operating with lower sympathetic activity and vascular resistance in space." (FRITSCH, 1996, apud BLABER, 2010, p.467).

The lack of gravity is directly related to the presence of cardiac changes such as hypotrophy and complications in inotropism, preload and afterload, these vascular changes appear to be associated with microgravity, which alters the morphology of the heart and the dynamics of the fluids involved in the process, therefore, there is a poor perfusion of liquids that accumulate in the upper limbs and a consequent lack of the same in the lower limbs, very often astronauts who have remained for a long time under the effects of microgravity present, when they are subjected to terrestrial gravity again, an orthostatic intolerance, this is due to a sudden inversion of these liquids where most of the blood that was located in the upper part of the trunk goes down to the legs and can cause fainting, dizziness and vomiting (JAMES P. 2021. P.1533).

2.2 MUSCULOSKELETAL SYSTEM

Loss of muscle mass and decreased bone mineral density also affects humans in terrestrial conditions, and does not occur exclusively in space.

> In general, biological tissues respond to mechanical stress from forces external to the organism, such as Ground Reaction Force and Gravity by modifying their properties, however, the absence of this stimulus also induces structural adaptations (MUELLER, 2002, p.2).

Tonus is understood as the ability of muscles to remain in constant contraction, this property is essential for the control of movement and for it to be possible to perform function with the muscles, however, it is not difficult to imagine that the muscles when exposed to the environment where it is no longer necessary to remain in constant contraction to perform activities, that some adaptations occur, even if these are not necessarily beneficial.

"The functional contractile activity of skeletal muscle is reduced during the process of functional muscle disuse accompanied by a reduction in amino acid carrier proteins" (UDAKA, 2011. p.1080).

> In an associated way, muscles kept in disuse are metabolically favorable to catabolic hormones, directing their metabolic pathways to mass loss, reduction of protein content and production of oxidative stress and/or reduction of antioxidant defense" (FERREIRA, 2004).

"Loss of bone density and musculoskeletal atrophy is a result of non-weight bearing and is one of the major concerns associated with the microgravity environment and spaceflight deconditioning." (NORMAN, 2000).

> Atrophy can be continuous or intermittent and eventually progressive until a new homeostatic set point is reached. These changes manifest in the way the body conserves and activates muscles and manages calcium and other minerals that are normally stored in the skeleton. Loss of total body muscle volume and strength causes decreased muscle force production and early muscle fatigability. In parallel with muscle atrophy in gravity-dependent muscles and at muscle-bone attachment sites, bone matrix and bone mineral are destroyed,

> leading to possible osteoporosis and loss of bone strength and increased risk of bone fracture. Increased urinary excretion of calcium and phosphorus (bone mineral constituents) may increase the risk of kidney stones or dehydration with hypercalcemia. These medical consequences of musculoskeletal atrophy may cause health problems for crew members or limit the success of the space exploration mission (VICTOR, 2016).

The process of loss of muscle mass and decreased bone mineral density is maximized due to the lack of indispensable stimuli that govern its structuring and maintenance process, even though astronauts are subjected to physical training consisting of aerobic and strengthening exercises for at least four hours a day during their stay on the international space station, in addition to the low nutritional quality of the food provided to astronauts due to the freeze-drying process, which although it has low nutritional content is necessary to carry and maintain supplies suitable for consumption during long periods of stay.

3 METHODOLOGY

This study is a literature review of the systematic review type, where the following platforms were used as a search base: SciELO; LILACS; PubMED; Medline; ScienceDirect; Cochrane Controlled Trials Database; New England Journal of Medicine; CORE; Circulation and Springer.

3.1 ELIGIBILITY AND EXCLUSION CRITERIA

The inclusion criteria were established with randomized articles that addressed at least one of the keywords mentioned above, the studies could use in vivo or in vitro tests, tests such as two-dimensional echocardiography with Doppler performed by a professional ultrasonographer, videos or pressure receivers that addressed and or corroborated the changes that occurred in the human body, human cells or animals, associating the microgravity environment as the main responsible for the changes that occurred in the systems: cardiovascular, bone, muscle, vestibular, optical, immunological and circulatory.

Literature reviews, studies that made use of in vivo or in vitro tests through exclusive exposure in simulations of *Weightlessness flights were* established as exclusion criteria, as it is understood that the human body, animal or tissue is not submitted for a sufficient time to present perceptible results and consistent with long-term exposures, thus presenting ineligible results.

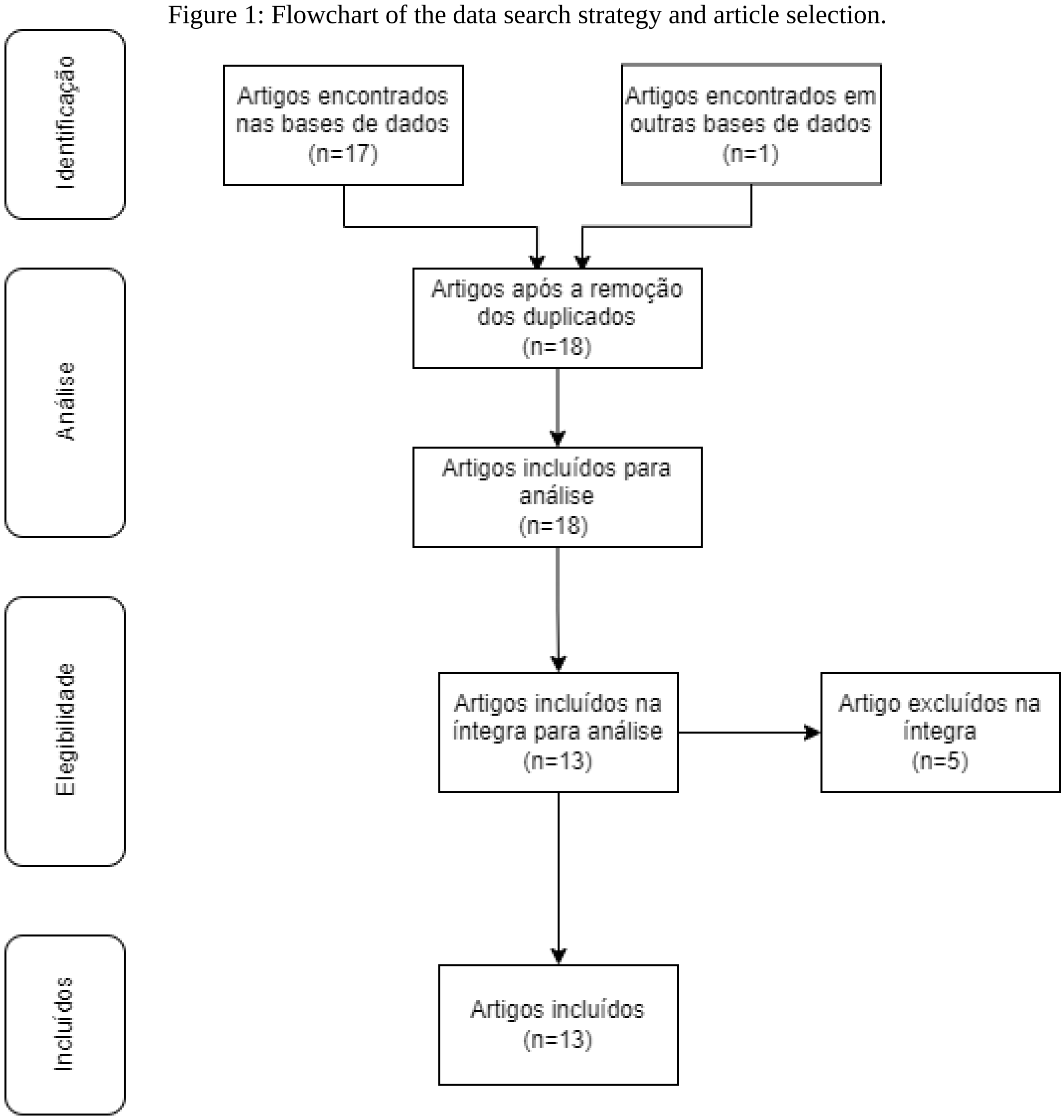
3.2 CRITERIA FOR SELECTION OF STUDIES

The admission process of these studies was carried out based on the analysis of an independent reviewer (B.L.C.P) strictly following the inclusion and exclusion criteria mentioned above. The studies were previously analyzed taking into account the title and abstract of the works, studies that after this brief analysis still presented potential eligibility for the study were selected for the evaluation of the textual content and finally, only the studies that passed were approved in this selection being included for qualitative synthesis. In cases where the studies were not available for the reviewer's evaluation, a free platform was used to release and analyze the full textual content. And finally, references of some included articles or excluded reviews were checked in order to continue the search for more relevant studies that could add to the theme.

4 RESULTS

Eighteen relevant studies were found through the SciELO; LILACS; PubMED; Medline; ScienceDirect; Cochrane Controlled Trials Database; New England Journal of Medicine; CORE; Circulation and Springer databases. Among these 13 studies were eligible, as all studies addressed at least one of the inclusion criteria. The flowchart showing the inclusion and exclusion process is shown in Figure 1.

Figure 1: Flowchart of the data search strategy and article selection.



4.1 CHARACTERISTICS OF PARTICIPANTS AND INTERVENTIONS OF INCLUDED STUDIES

Of the eighteen articles included, sixteen corroborate at some level for health, better perception of risks and side effects, in addition to studying training models that can promote a longer stay safely of astronauts in the microgravity environment, one of the articles addresses the human evolutionary process as a whole, and another addressed the nuances of the biological evolutionary process of the human being.

A group of astronauts were subjected to a series of prescribed exercises beforehand during their mission on the Mir space station, these exercises were catalogued and analyzed by video and a series of pressure sensors scattered around the spacecraft studying motor abnormalities and any compromises in strength, Another study subjected a group of eighteen astronauts to an MRI scan before and after exposure to long-term missions on the international space station in order to analyze the narrowing of the central sulcus and edema in the optic canal. The characteristics of the participants are described in Table 1 and the interventions of the included studies are described in Table 2.

Table 1: Characteristics of the participants.

Primeiro autor	Ano	População	Tamanho da amostra
Dava-J.Newman	2001	Astronautas	_
Donna-R.Roberts	2017	Astronautas	34
James-R.Macnamara	2021	Astronauta e nadador	2
Vitor-S.Schneider	2016	Astronautas	16

Table 2: Interventions of the included studies.

Autor	Ano	Objetivos	Resultados
Dava-J Newman	2001	Graduar os distúrbios causados pelo ambiente de microgravidade aos astronautas e quantificar as forças exercidas pelos astronautas a estação espacial durante uma missão espacial por meio de equipamentos de vídeo e sensores espalhados pela estação.	As adaptações geradas pela microgravidade induzem os astronautas a exercer menos força e realizar movimentos mais lentos, o pico mais alto de força foi de 137 Newtons ou aproximadamente 13.9701kgf, já a maior parte da força exercida pelos movimentos era de 9 Newtons ou aproximadamente 0.9177 kgf.
Donna-R Roberts	2017	Identificar e comparar as alterações encontradas no líquido cefalorraquidiano e deslocamento de estruturas cerebrais de astronautas submetidos a missões espaciais de curta e longa duração por meio do exame de ressonância magnética.	O estreitamento do sulco central, deslocamento do cérebro, estreitamento dos espaços do líquido cefalorraquidiano e edema do disco óptico foram algumas alterações encontradas, sendo estas, muito comuns em astronautas submetidos a voos de longa duração aproximadamente 164,8 dias.
James-R Macnamara	2021	Comparar os efeitos cardíacos da longa exposição as viagens espaciais e a natação de longa duração, investigando os parâmetros de massa corporal e volume sanguíneo pelo método Teichholz.	A redução da massa do ventrículo esquerdo foi identificada em ambos os pacientes do estudo, sendo ligeiramente mais acentuada no paciente que foi exposto a viagem espacial, não sendo possível descartar a variável fisiológica de ambos pacientes para o resultado encontrado, também não foi possível identificar diminuição da fração de ejeção do VE.
Victor-S.Schneider	2016	Analisar os riscos a saúde humana causadas pelas adaptações musculoesqueléticas da microgravidade bem como seus mecanismos de adaptação e contramedidas eficazes utilizadas nos voos espaciais.	Os seres humanos que se expõem ao ambiente de microgravidade desenvolvem uma atrofia muscular esquelética quando nem uma contramedida é utilizada, a perda do volume e força muscular total está associado a diminuição da produção de força e rápida fatigabilidade muscular, o mineral ósseo é destruído levando a possível osteoporose e aumento do risco de fratura óssea, o aumento da excreção de cálcio e fósforo pode aumentar o risco de cálculos renais e desidratação associada hipercalcemia.

5 DISCUSSION

Despite the techno-scientific evolution, there are still very few data that can be analyzed and compared in relation to the population and the changes associated with the microgravity environment of the study, it is possible to support this statement based on the reduced number of published articles with good methodological quality and that managed to reproduce and study the data of the population, before, during and after exposure.

This scarcity of data may be associated with the high costs to start these surveys, which are commonly funded by private companies, which almost always have a profitable bias behind the research, data collection during exposure often needs to be done among the population itself, the development of new research is also surrounded by ethical dilemmas, since long periods of exposure and permanence need to be reduced as much as possible due to the risks to the astronaut's health.

Even though it is notorious the difficulties about the execution, collection and applicability that touch the subject in question, the studies already published presented a series of physiological changes in the human body when exposed to the microgravity environment for short and long periods, it was also possible to suggest that such complications could be potentiated if they were already established previously, acting as an aggravating factor, it is understood that the severity of these changes is also associated with the time of exposure to the environment and that they tend to intensify in case of prolonged exposure, bringing serious risks to the integrity of the astronaut's health.

6 CONCLUSION

It is concluded that there is a scarcity of studies on this subject, this due to a series of difficulties, from its applicability, collection, cost and control. However, the few studies found with good methodological quality are unanimous regarding the physiological changes in the human body, which are extremely harmful to health, especially when exposure lasts in the microgravity environment, it is also understood that the rehabilitation process after returning to terrestrial gravity tends to be slower and more careful when the exposure time is prolonged, Finally, aerobic exercise protocols would be associated with a decrease in bone mineral loss and muscle hypotrophy due to the absence of gravity, minimizing damage to the musculoskeletal system during exposure, as for hydrostatic changes and the circulatory system, it has not yet been possible to establish effective measures to mitigate the harmful effects on the body.

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