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作品名稱	Automated Alternative Compression/Traction of Lower Extremities AACT as a Musculoskeletal Countermeasure to Mitigate Bone Loss and Muscle Atrophy in Microgravity
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Research

**Automated Alternative Compression/Traction of Lower Extremities
AACT as a Musculoskeletal Countermeasure to Mitigate Bone Loss and
Muscle Atrophy in Microgravity**

Research proposal

Introduction:

Space Medicine and relevant sciences are still considered a new era; the first humankind steps toward the space took place since less than 60 years. It has been noticed the adverse effects of microgravity on the human body in different aspects, our concern here is the musculoskeletal aspect. On the ground we didn't notice how we can stand up, or how our muscles and bones of the lower limbs can keep us standing up right. This is by a complicated process including the bones, the equilibrium, and the anti-gravitational muscles of the lower limbs which occurred without thinking about it. The force of Earth gravity against our bones of the lower limbs makes them harder and makes the muscles stronger, because they are interfacing the earth gravitational force every moment we are standing up, as per Newton's third law (for every action in nature there is an equal and opposite reaction), such forces are unavailable in space and its effect being obvious on arrival to earth after long stay space flights, so being unable to keep standing upright easily on their arrival. On return to earth the routine medical examinations revealed loss of astronaut muscle mass and bone density particularly of their lower extremities because they did not use them in space for a long time.

Currently, astronauts on board of ISS (International Space Station) they accomplish daily tasks including resistive exercises ARED "Advanced Resistive Exercise Device" in form of treadmill, ergometer, and weightlifting machine, to decrease the loss of bone density and muscle mass of their lower limbs. Despite their discipline to those exercises they still lose 1-2% of the muscle mass and bone density that give importance to add some protective measures to keep their muscles and bones healthy.

Through this article, the idea is to make a device such AACT (Automated Alternative Compression/Traction) to be applied daily to the astronauts lower limbs as part of their daily exercise during space flight to give push/traction forces to astronauts lower limbs to prevent or at least decrease such loss, by AACT we are mimicking the gravitational force of earth on astronauts lower limbs during long space flights to let them be healthy till they come back.

Aims:

1. To mitigate the loss in muscular mass and bone density due to microgravity by creating a device that can reduce the damage.
2. To provide a beneficial device as a part of the mandatory exercises for astronauts during space flights that can help to prevent the adverse effects of microgravity on the musculoskeletal system.
3. For possible longer future space flights longer without worries of the microgravity on the astronaut's musculoskeletal system.

Objectives:

1. Reducing the damage caused by Microgravity on muscle mass and bone density.
2. Creating a device that can help astronauts in microgravity and limit any possible damage on the musculoskeletal system.
3. To install the AACT and use it as a countermeasure to alleviate bone loss and muscle atrophy in microgravity.

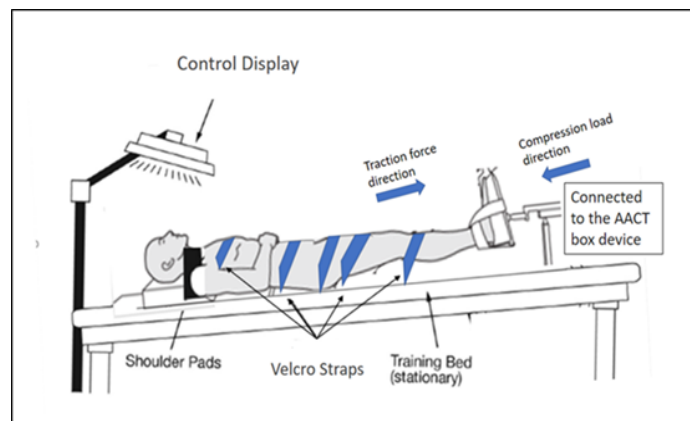
Literature review:

As the push for human spaceflight intensifies and commercialization of spaceflight accelerates, an increase in human missions into space is unavoidable. However, such a venture would be fraught with risk due to the lower gravitational force that would be encountered during spaceflight, which would significantly disrupt a variety of physiological systems. The most significant system that would be affected by this would be the skeletal system, as the effects of microgravity on both skeletal muscle cells and skeletal muscle stem cells would have a significant clinical impact. This review will provide an overview of recent advances in the understanding of how microgravity exposure to the skeletal system affects the skeletal system. Additionally, it will discuss the mechanisms underlying bone and skeletal tissue loss associated with microgravity exposure, and provides an overview of the countermeasures currently being evaluated. Finally, it will identify the gaps in current knowledge and explore new avenues of research as we move forward with the pursuit of manned spaceflight [1]. As humans spend more and more time in space, 1-2% of their bone mass every month is lost as a result of microgravity exposure. It is clear from data gathered from astronauts and from space research on animals and cells that microgravity causes skeletal deconditioning in weight-bearing bones. This review highlights claims made in recent research on the effects of microgravity on non-weight-bearing bones; various bone compartments, and the skeletal recovery process in data from human and animal spaceflight. Space experiments are not easily accessible, and technological and logistical constraints frequently restrict the scope of experiments. This study presents a wide range of field studies that use microgravity simulation technology to clarify the complex process of bone loss [2]. Microgravity (μg), which space traveller's experience, causes increased bone loss in comparison to age-related bone loss on Earth. Space exploration is hampered by the higher bone turnover that microgravity causes. By using resistance equipment or treadmills for exercise, one might slow down this bone loss. This systematic review goal is to present a current overview of the state of the art in the subject of space bone loss and potential remedies for it. After searching PubMed and Scopus for 482 distinct studies, 37 of them satisfied the eligibility requirements. The results of the research indicated that there was a larger rise in bone restoration during μg , despite enhanced bone growth. Various forms of physical activity, pharmaceutical interventions using bisphosphonates, and RANKL antibody (receptor activator) [3]. Space colonization poses a significant challenge for humanity due to various obstacles that impact the success of space missions. One major concern is the absence of gravitational forces, which leads to physiological changes in the musculoskeletal system. Astronauts often experience a decline in bone density and muscle mass, known as osteoporosis and sarcopenia. To address these issues, space medicine plays a crucial role in developing strategies to prevent or counteract the negative effects of weightlessness. Additionally, studying the biological effects of weightlessness can provide valuable insights into adapting to

spaceflight and potential treatments for maintaining musculoskeletal health in microgravity conditions. Therefore, this study aims to summarize recent evidence on the impact of real and simulated microgravity on the musculoskeletal system and discuss the effectiveness of defense strategies used in real and experimental scenarios [4]. Exposure to microgravity in space causes various changes in the body that can negatively impact the health of astronauts. These changes are primarily related to the lack of physical activity, which affects different systems and organs in the body, particularly the musculoskeletal system. This can lead to symptoms similar to those seen in older individuals on Earth, such as muscle loss and weakness. These Effects, known as sarcopenia, are a major concern for both astronauts and the elderly population on Earth. It is important to identify biological markers and understand the underlying molecular mechanisms of these effects in order to develop effective interventions. Research in the field of Geoscience, which focuses on the biology of aging, can provide valuable insights for addressing the adverse effects of microgravity. Sarcopenia and frailty, which are often linked in older individuals, have similarities to the changes seen in astronauts after space flight. This article aims to explore the biological mechanisms of sarcopenia and frailty and how they relate to the effects of microgravity on astronauts [5].

Methodology:

An advertisement was published at King Saud University (KSU) searching for volunteers (male only, from the age range of 25 to 35 years old, and with an average physique) needed for a research study. There were 80 subjects from KSU population who volunteered in this study that had the last 3 digits of their ID number odd. The experimental procedure was approved and conducted by King Faisal Specialist Hospital & Research Centre (KFSHRC), all subjects were required to be free of any lower limb injury and do not have a history record of any illness or disease. They were provided with a written consent and a reasonable price on conditions that they do not move for two months lying on bed. Upon arrival, we started taking DEXA scan, MRI, and blood tests, to see their bone density, muscular mass, and to measure the amount of calcium and vitamin D in their blood [6]. The device used in this study is a custom built, and would be determined by the help of King Abdulaziz City for Science and Technology (KACST). The AACT device manufactured to apply push forces alternating with traction forces for each extended lower limbs as one unit extend from the palm of the foot to the mid of thigh by straps that wrap around the leg and thigh, this dynamic alternative push/traction applied for each leg, hence mimicking the action of standing on earth however this process takes place in a laying down position. As it pushes the leg it will move the leg from bottom to up in a horizontal-laying on spine position, therefore it gives pressure from down the foot to up the thigh, but it will not actually be from down to up because the person is lying on their spine. So it will be giving pressure from the foot towards the body and when it pushes and releases pressure it will push as one unit for the foot, leg and thigh by straps connected as one push. According to the physicist it will give a push that can be tolerated by a person that seems to be like the pressure when we stand on the ground that mimics the force of gravity on earth. So it will be tolerable and it will be alternatively applied on one lower limb then shifted to the other one for a couple minutes. This whole process will approximately take three hours as one session, and has to be done twice a day.



Results:

At the end of the period of the study (two months) with the sample size of 80 subjects, we can proceed to the results if less than 20% of the volunteers did not continue the study, but if more than 20% of the volunteers did not continue it will affect the study. Among the experiment group and the control group we will repeat the same blood tests as we'll also repeat for each person the same MRI for the lower limbs and bone DEXA for bone density. Then by the statistician we collect the data and compare in the experiment group before and after the study as well as the same for the control group before and after and we'll see if the t-value is greater or not. In the control group we'll compare the data before and after, and then we're going to determine the percentage of damage that happened to the muscle mass and bone density. In the experiment group we'll compare the data before and after, and then we're going to determine the percentage of damage that happened to the muscle mass and bone density. Finally, we'll compare between these two collecting the table data, if we find in the experiment group there was less damage than those in control group, that means it is a protective device and we will recommend to add this device for astronauts. If the improvement is not that significant and the results of the experiment group and control group seems to be similar, then that means this device did not add any benefit so no need for it.

Conclusion:

By collecting the data if we find a significant difference by 50% more between the two groups (the experiment and the control group) we will consider this device protective and we'll recommend it to astronauts. If there wasn't a difference found by 50% or more then it is not needed and there is no benefit from this device.

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1. Novelty and Significance:

This science project addresses a critical issue in space medicine: the adverse effects of microgravity on the musculoskeletal system of astronauts during long-duration space flights. The proposed Automated Alternative Compression/Traction (AACT) device represents an innovative approach to mitigating muscle mass and bone density loss in microgravity environments. By mimicking Earth's gravitational forces on astronauts' lower limbs, the AACT device aims to complement existing exercise regimens and potentially enhance the overall health and performance of astronauts during and after space missions. The significance of this research lies in its potential to improve the long-term health outcomes of astronauts and possibly enable longer space missions with reduced physiological risks.

2. Strengths:

The project demonstrates a strong understanding of the physiological challenges faced by astronauts in microgravity and proposes a well-thought-out solution. The experimental design, including a control group and a sample size of 80

subjects, shows a commitment to scientific rigor. The use of multiple assessment methods, such as blood tests, MRI scans, and DEXA scans for bone density, provides a comprehensive evaluation of the device's effectiveness. The project also considers practical aspects of implementation, such as integrating the AACT device into astronauts' daily exercise routines. The clear objectives and methodology for data analysis, including statistical comparisons between experimental and control groups, demonstrate a systematic approach to evaluating the device's efficacy.

3. Weaknesses:

Despite its innovative approach, the project has several limitations that need to be addressed. Firstly, the study lacks a detailed comparison between the AACT device and existing countermeasures like the Advanced Resistive Exercise Device (ARED), which limits the contextual evaluation of the new device's benefits. Secondly, the use of a bedrest model to simulate microgravity conditions does not fully replicate the physiological effects experienced during actual spaceflight, potentially affecting the direct applicability of results to astronauts in space. The abstract mentions that the experiments have not yet been conducted,

which means the project is still in a conceptual or early planning stage. This lack of actual data limits the ability to assess the device's real-world effectiveness.

Additionally, the project report should include a formal abstract to provide a concise overview of the research. These weaknesses suggest that while the concept is promising, further development and actual experimental data are needed to fully evaluate the potential of the AACT device in space medicine.