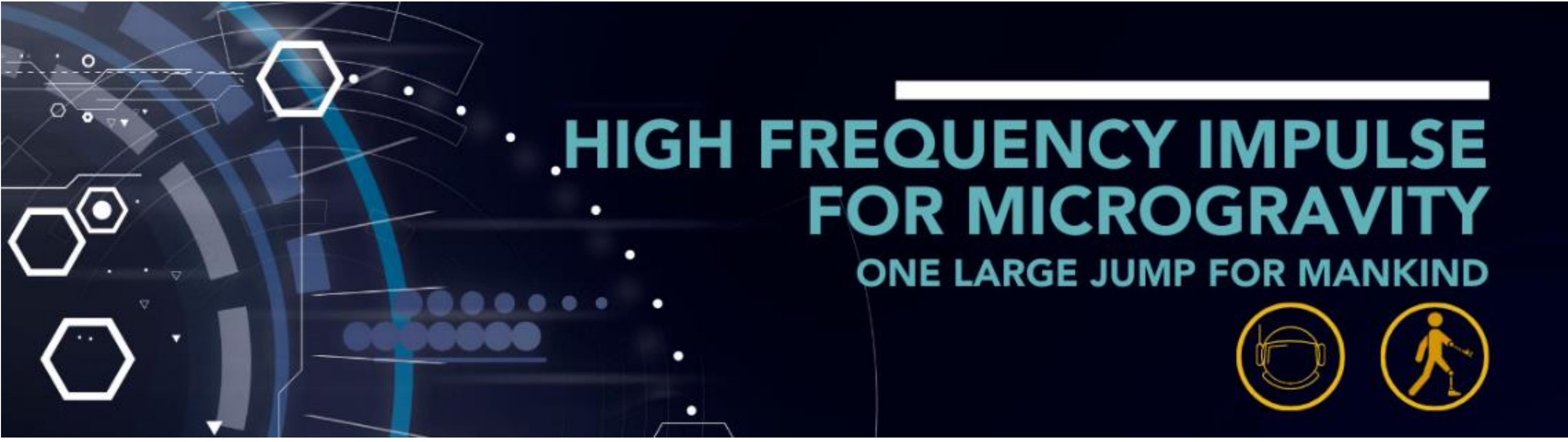


Quick info

Developed by: Physical Mind London

Headquarters: United Kingdom

Year of Release: 2016

Associated Paper

Website

Product type: Exercise device

Space technologies: Space exploration

Primary application: Physical rehabilitation

> *"I think in total, HIFIm enables humans to operate healthily and successfully in space and terrestrially. The phrase "use it or lose it" is very apt; we have to keep moving and exercising as best we can, both for our own health and for the well-being and future healthcare of nations around the world."*

- John Kennett, founder and CEO of Physical Mind London

What does HIFIm do?

HIFIm, or the High Frequency Impulse for Microgravity, is an exercise countermeasure.

HIFIm enables multiple exercises to mitigate bone, muscle and cardiovascular deconditioning. In space astronauts can lose up to 1.5% of their bone mineral density per month; "jumping" and the other exercises performed on HIFIm help mitigate this. Essentially, individuals lie on their backs, legs bent and feet pushing onto a vertical "jump board": Pushing from the legs, the individual slides away from the jump board and returns safely back on the jump board.

HIFIm is also useful in terrestrial clinical rehabilitation for those who suffer from osteoporosis, and also for Individuals who have had a leg partially amputated. Jumping on HIFIm helps build and maintain muscle and bone density. Progressively increasing the proscribed dosage of exercise load, amputees can condition the junction between their prosthetic and leg stump.

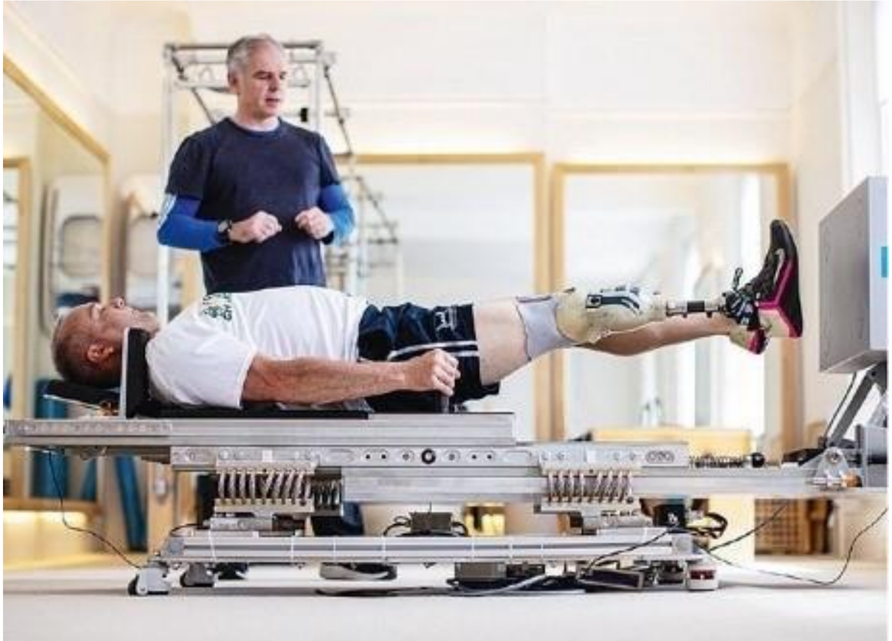
It can therefore be used by astronauts aboard the International Space Station to prevent muscular, bone and cardiovascular degradation.

HIFIm is designed such that it does not transfer vibrational forces on spacecraft and does not require any electrical power from the spacecraft to operate.

How does HIFIm work?

According to John Kennett, HIFIm's creator, "HIFIm is uniquely designed to allow an individual to jump repeatedly in zero gravity. We made a machine that has an upper and lower carriage which slide linearly at the same time; they're synchronized mechanically through the high tensile springs which we used to attach them. The individual will be lying down supine, on their back, and we have what's called a jump board which they put their feet flat on with their knees and hips bent. We also have shoulder pads which their shoulders are pressed up against.

We ensure that the upper carriage and the lower carriage have equal mass so we can attach some mass balance weights to the lower carriage. We create an equilibrium between the two carriages, then the individual can start jumping, or initially just pushing out to straight legs and then returning, because the force of the springs Intriguingly, the load and



Source: Physical Mind London

vibration that's generated through any form of exercise on a space station or a spacecraft has to be reduced to the absolute bare minimum. We therefore ensured that HIFIm nullifies its own forces and vibrations through Newton's laws regarding equal and opposite reactions by having upper and lower carriages of equal mass. This means that HIFIm can have a quite lower mass than the current exercise counter-measures considering it is its own vibration and isolation system." The entire system is mechanical and does not require a power source from its environment.

Who can HIFIm help?

HIFIm can help individuals with a variety of disabilities and health conditions. One of its main applications is for individuals who have lost a leg or part of a leg. Amputees often experience muscular degradation of the remainder of their amputated leg due to disuse. They may also experience osteopenia or osteoporosis in bone of their remaining leg. By isolating and exercising those muscles, HIFIm encourages muscle growth and maintenance and therefore prevents muscular and bone degradation. Exercising muscles near the site of the amputation also helps the skin in the area tighten and heal smoothly.

HIFIm can also be used by individuals who have been confined to a bed by various health conditions. Individuals on bedrest often also experience muscular weakening and osteoporosis because their muscles tend to not be used. HIFIm is horizontally oriented rather than vertically, so even if an individual cannot stand, the individual can be moved from bed to HIFIm, do a set of exercises, then moved back to their bed. This both prevents muscular degradation for individuals on long-term bedrest and can build muscle in preparation for a surgery, improving success rates.

Finally, HIFIm has applications for elderly individuals who have naturally developed osteoporosis over the course of their lifetime. By providing a lower-impact exercise regime, it makes exercise more accessible to the elderly, reducing the effects of osteoporosis and encouraging stability and muscle growth. This stability and muscle growth can increase older individuals' independence and prevent falls or other accidents common among the elderly.

Because HIFIm can be loaded with a controlled amount of weight and resistance, it can be catered to the strength and needs of the individual using it, allowing it to be applied to a range of disabilities.

How is HIFIm being implemented?

HIFIm has patents and patents pending and is commercially available for space and terrestrial use.

The UK Space Agency continues its support, funding HIFIm's further testing, research and development. Physical Mind London is also in discussion with organizations such as the military, NASA, ESA. In the past months Canada and United Kingdom have formed a bilateral agreement over HIFIm, with Physical Mind London being awarded a substantial grant to implement HIFIm into Canadian Space Agency's Lunar programme.

Physical Mind London is also in talks with medical specialists and individual amputees to develop and test HIFIm in preparation for terrestrial applications for people with disabilities or health conditions.

An Interview with John Kennett, HIFIm's Creator

What was the motivation behind creating HIFIm?

In around 2011 or 2012, I was working with patients and clients that are rehabilitating from having cancer. One individual had just had breast cancer, so she had a mastectomy and breast reconstruction. During her rehabilitation, she said that she was suffering from low bone density due to radiotherapy and their treatment. She asked if I could do anything about it, and that got me thinking. With the equipment that was in my rehabilitation clinic, we created a system where we could get an individual who was lying down horizontally to jump, putting some ground reaction forces, some load and strain and stress, through their skeletal system. We devised an exercise programme which enabled this woman to work very hard over the course of the year. She was about 60 years old at the time, and at the end of the year (and this is an unscientific, non-clinical trial) she had another bone density scan and her overall bone density improved by 8%, which is amazing.

I'm a former aerospace engineer, and I'm intrigued by space, so I looked into what they're doing on the International Space Station in terms of their exercise countermeasures. They need to counteract the effects of being in zero gravity, which include the deconditioning of the body through reduced bone density, reduced muscle mass, and cardiovascular issues. I learned that on the International Space Station, they have three exercise machines, and after reading the papers produced by NASA, I realized they're missing a trick. From that, I devised and designed HIFIm, which stands for High Frequency Impulse for Microgravity. That led me onto this journey, which has taken me here today, which is the International Space Station Research and Development Conference where we've been presenting the findings of our work.

Could you say a little bit more about how you began working with ESA and the UK space agency?

When I began designing HIFIm, I kept it a secret for a long while. I worked on the principles and started sharing those principles with universities, some of which I collaborated with to carry out physiological research. As time went on, I contacted the UK Space Agency, who were very encouraging, and they said the best thing I could do was contact the European Space Agency. That sent me on a very long journey which found me traveling all the way to the European Space Agency's Technical Research Centre in The Netherlands and sitting down for a meeting with people (mostly professors) from around Europe, all desperate to get their research onto the International Space Station.

By this point I'd realized I needed to team up with an academic institution, and as time went on, I contacted a very specific individual, Professor Daniel Cleather, who I knew from my time as a visiting lecturer at his university. He had all the right attributes, skills and knowledge to further the academic side of HIFIm's journey. I also contacted an amazing, dynamic, Oscar-winning special effects engineering team who had worked on films such as Star Wars, Mission Impossible, and the Bond franchise. We partnered up to put my designs into practice, and the European Space Agency was very interested, so they put out a call to all the European nations to see if anyone could create an exercise countermeasure.

Unfortunately, I found that the paperwork and red tape were such a burden that we decided to go ahead and build HIFIm without any input from the European Space Agency or UK Space Agency. I partnered with Dominic Tuohy and his special effects team, who were the Oscar winners for their work in 1917, and with his lead engineer Vince Abbot, within a couple of months we built and manufactured the first prototype of HIFIm. With that, I went to the European Astronaut Centre in Cologne and presented a video of our findings, which absolutely blew them away. For one, they couldn't believe that it was created so quickly and that the prototype was already almost perfect to go into space. Upon returning that weekend to my base, which is in Teddington in London, one of the heads of the UK Space Agency came to visit. Basically, as soon as I landed, a brilliant individual called Libby Jackson (now Head of Space Exploration at the UK Space Agency) was waiting for me at my base, and she started to assess HIFIm. To her credit, she actually tested HIFIm herself. She did all the exercises, and from that moment on, she knew that this would be a groundbreaking piece of exercise equipment. The UK Space Agency, therefore, in collaboration with the European Space Agency, felt it was something very much worth backing.

From that point, we were incredibly lucky because the European Space Agency allocated us their astronaut time or what's called a parabolic flight campaign. We had the opportunity to go into zero gravity onboard an aircraft, which, I am told, was the first time in the history of the European Space Agency where they passed on all their astronaut time to an individual company. The UK Space Agency was also fantastic. They funded our team in preparation to go on these parabolic flights where we could test HIFIm in zero gravity. Our team flew over to Bordeaux, where we set up our equipment on board the aircraft. Our first flight enabled us to get 31 parabolas, and on each parabola, which is like a roller coaster going up and down, you experience flying along on a nice horizontal level flight path at 1G and then the plane pulls up, and as it pulls up, you start to experience nearly 2G. Then, when you get close to the top of the parabola, the pilots call out the word injection, which means they are injecting or throwing us into zero gravity for about 22 seconds.

During that moment, we wanted to answer two questions. One, can an individual jump repeatedly on HIFIm in zero gravity? Two, can we mitigate the forces and loads and vibrations going to and through the supporting structure? During that first parabolic flight campaign, we carried out 93 parabolas, which was 34 minutes of being in zero gravity, and we answered those questions very successfully. Yes, we can jump repeatedly in zero gravity, and yes, it does offload the forces and vibration that's going through the actual aircraft structure, which replicates the spacecraft or space station. We also during that time invited on our parastronaut analog tester, and before the flights, in a terrestrial environment, we had carried out a feasibility study with an amputee. That was the start of a fantastic journey for us.

On that note, how did you incorporate feedback from the parastronaut and any other folks with disabilities that you've worked with? How have you gone through testing with them and then integrated their feedback to change or adapt your system?

The European Space Agency issued a request for people with specific disabilities to apply to become a parastronaut. Knowing this was going to happen, I contacted an amputee by the name of Lee Spencer, who's a former Royal Marine Commando, and who, as a disabled individual, holds 4 world records for rowing the Atlantic. Lee is an amazing individual, and I invited him to come along and carry out a feasibility study in our base in southwest London. This was about seven years after Lee had lost his leg, which was from a motorway car accident where he was helping individuals, saving their lives, and he sustained a life changing injury in the process. So Lee joined our team for this feasibility study.

Not only that, the very first time he experienced seeing and using the equipment, the Forces News, which is the British Media Association for the Armed Forces in the UK, also joined us and were filming his reaction live. There was quite a bit of excitement, but also a little bit of pressure. It was exciting because individuals like Lee with a below the knee amputation generally wear a prosthetic. When someone's lying on their back and they're on HIFIm, we’re able to administer a dosage of exercise so we can create the level of force that's going to go through their musculoskeletal system. Initially, we got Lee to just push in and out and get used to that level of force going through his limbs, spine and shoulders. Then, when Lee felt comfortable, he started jumping. As he said, this was the first time in seven years that he considered that he might be able to get airborne, be able to jump from a surface and land again, and it went incredibly well. He was jumping bilaterally, pushing out with both legs, and then he jumped unilaterally using just his prosthetic limb and the forces going through the stump of his leg through to the prosthetic.

Through administering the load, we’re able to dictate the points where the prosthetic and the stump interact and the force they exert against one another. This helps condition and tone up the skin around that area, but also the improvements in muscle mass and bone density help people who have lost a limb. When an individual loses a limb, they experience localized loss of bone mineral density, which is called osteopenia, the precursor to osteoporosis, and that can occur in a very specific place, such as through that hip joint of the amputee limb and running through any bone that's left in the limb.

Can you speak of any challenges you faced in HIFIm's development?

HIFIm is a very new form of exercise countermeasure in the space environment, and convincing organizations such as NASA, ESA and the UK Space Agency that HIFIm was their path forward took a bit of time. Encouragingly, though, ESA carried out a bedrest study at one of their bases in Cologne, where many individuals volunteered to actually be in bed for up to 60 days with their head tilted down at a six-degree angle. This was meant to replicate the deconditioning that happens when astronauts are in zero gravity, and during that time they carried out a form of exercise countermeasure where individuals would jump on another horizontal platform that enabled them to create high ground reaction forces through their skeletal system. From that, they found that HIFIm could reduce the exercise time required on the International Space Station, which is currently 2.5 hours per day, including setting up the equipment, using the equipment and then breaking that equipment back down so the astronauts can get back to their normal office day on the ISS. They found that with HIFIm, four to six minutes of exercise per day, which roughly equates to about 50 jumps with quite high ground reaction forces, mitigates the deconditioning of the body. Interestingly, 30 minutes of exercises using HIFIm could free up an extra 22,425.6 hours of astronaut time on the International Space Station.

After our first exploration into parabolic flights, we built version two of HIFIm, and we made it even smaller. Our goal was to ensure that we could control and really reduce the amount of forces and loads going through the spacecraft. Using an aircraft, we carried out another series of parabolic flights to prove quite categorically that we could reduce the forces, loads, and vibration and also reduce the amount of time that astronauts would need to spend exercising in space. We also realized we don't need to draw any power from a spacecraft or a space station because we’re self-contained. Not only this, but using the movement of HIFIm, we might in fact generate power for the space station. We had a few issues at the beginning of our prototype, but the test equipment we were using was so bulky and heavy that we weren't sure if that was affecting our results. When we built version two, we took off some of the very heavy test equipment, and the results proved that HIFIm was absolutely perfect for doing the job it was designed for.

Do you have any plans for either new future projects or some kind of addition or change to the HIFIm system, anything you're looking towards?

This current version of HIFIm is good to go to space right now, but we're also in the position where using our special effects engineering team, Dominic Tuohy and Vince Abbott, we can very quickly adapt to any space company or space station's needs and requirements.

Space agencies are also very interested because not only can we operate in Low Earth Orbit (LEO), we are also looking to be on board really exciting projects such as Gateway, which is the space station plan to go around the moon. There are also plans to set up a habitat on the moon, which has about 1/6 of Earth's gravity. Anybody who's going to be spending time orbiting the moon or living on the moon needs to have some form of exercise countermeasure to mitigate the effects of deconditioning. People are also talking about going to Mars, which is an extraordinary exploration for humans to even consider. On that journey too, astronauts will need a very specific exercise countermeasure to ensure that when they arrive at the Martian landscape, their bodies are in a position to enable them to operate, to actually take steps and walk and function on the Martian landscape. From a space station sort of environment, there is such an exciting buzz around HIFIm, but that also translates to the rest of the solar system and to applications right here on Earth.

Do you have any parting thoughts you'd like to leave us with or anything you'd like to expand on?

HIFIm is fundamentally designed for going into space. Its mechanical properties and designs enable astronauts to exercise in zero gravity. However, the terrestrial applications are also huge. The effects of osteoporosis, low bone mineral density, on the population are huge. In the UK alone, based on the British health service figures that are available, it costs the NHS England £4 billion per year to deal with osteoporosis related situations. There are many ways in which individuals suffer from osteopenia and osteoporosis. Using HIFIm, we're able to administer a dosage of exercise, which means we can take someone who's quite fragile and potentially older and support their body, then start to apply the exercises which will build their muscle mass and help improve their bone density.

That is a great spinoff because someone who's suffering from very low bone density is at risk of fractures, but by improving their bone density just a small amount, fracture risk reduces massively, so a small improvement in bone mineral density really means that that person's bones are less likely to break in a fall. Not only that, their muscle mass improving means that they are going to be more stable in their walking, which means that simple things like stepping up and down stairs, getting in and out of a chair, stepping up a curb, crossing a road, and other functional actions become much easier. These elements are fundamental in how people of an older generation take care of themselves and "use it or lose it." It is so apparent because as people get older, they often tend to not exercise as much even as their muscle mass reduces. Strengthening their muscles means they are more independent for longer. Home help is then offset by a long way because someone's a little bit more mobile and less likely to have a fall. It's preventative healthcare and a reduction of the load on a nation's healthcare system.

Taking that aside, we're also working with amputees. We can start rehabbing individuals who have lost a limb, and instead of being vertical in 1G and forcing down their body weight through their limb, we're able to put them on their back and then gradually increase the load that is going through their body. If it's a single-leg amputee, we can start to condition and tone their stump, and that in itself will increase their recovery time and also improve the mineral density of remaining bones. This has implications as well for young people; we've had pediatricians ask if we could use HIFIm on children who have been bed bound for a very long time to rehabilitate and strengthen their bodies. It was an area we hadn't thought about until that point, so we realized this benefit that can be given to anyone who's spent a long time in bed, which weakens muscles and bones. Even if a person is completely bedridden, we can lift them up on a winch, put them onto HIFIm, get them to exercise, lift them back onto the bed, and through seven weeks of preoperative exercise work, prepare them for their operation. Then, postoperative, we can deal with the rehab, and that again is really exciting. We realized that we can cover the older generation and we can cover the younger generation by helping people with certain disabilities.

On another spectrum, which is also exciting, we have the military interested. Soldiers, especially female soldiers, tend to receive a lot of stress fractures throughout their time in the military when they are being loaded, running around with big rucksacks, and exercising in confined spaces on naval vessels. Aboard ships and submarines, there is a use for something like HIFIm, and that's really exciting.

I think in the current situation, with all nations' health care systems, we really have to start looking at preventative healthcare and enabling and encouraging people to exercise and take care of their health. We need to remind them that our bodies are phenomenal and we really, really should respect them and take care of them by improving our health and wellbeing. It's never too late to start exercising correctly, and that is only going to benefit us. It doesn't matter if you're starting from an early age, midway through your life, or if you're in the later years of your life. All exercises done correctly are going to improve you and make you more efficient, more happy, and functionally more able to interact you're your loved ones in a more enjoyable way.

ABOUT

This article is part of the "From Space to Earth: innovations enabling accessibility on Earth" project under the United Nations Office for Outer Space Affairs Space for Persons with Disabilities initiative. This project aims to raise awareness of the benefits of space technologies, spinoffs and related innovations in addressing challenges of disability, and to foster international and interdisciplinary collaborations on technological solutions to advance accessibility and empower persons with disabilities. This project contributes to the implementation of SDG 10: Reduced inequalities.

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