Ames

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

REPLY TO ATTN OF: GP

TO: USI/Scientific & Technical Information Division
Attention: Miss Winnie M. Morgan

FROM: GP/Office of Assistant General Counsel for Patent Matters

SUBJECT: Announcement of NASA-Owned U. S. Patents in STAR

In accordance with the procedures agreed upon by Code GP and Code USI, the attached NASA-owned U. S. Patent is being forwarded for abstracting and announcement in NASA STAR.

The following information is provided:

U. S. Patent No. : 3,550,585

Government or Corporate Employee : Government

Supplementary Corporate Source (if applicable) : NA

NASA Patent Case No. : ARC-10100-1

NOTE - If this patent covers an invention made by a corporate employee of a NASA Contractor, the following is applicable:
Yes ☐ No ☒

Pursuant to Section 305(a) of the National Aeronautics and Space Act, the name of the Administrator of NASA appears on the first page of the patent; however, the name of the actual inventor (author) appears at the heading of Column No. 1 of the Specification, following the words ". . . with respect to an invention of . . ."

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Enclosure
Copy of Patent cited above

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PATENTED DEC 29 1970 3,550,585

SHEET 1 OF 3

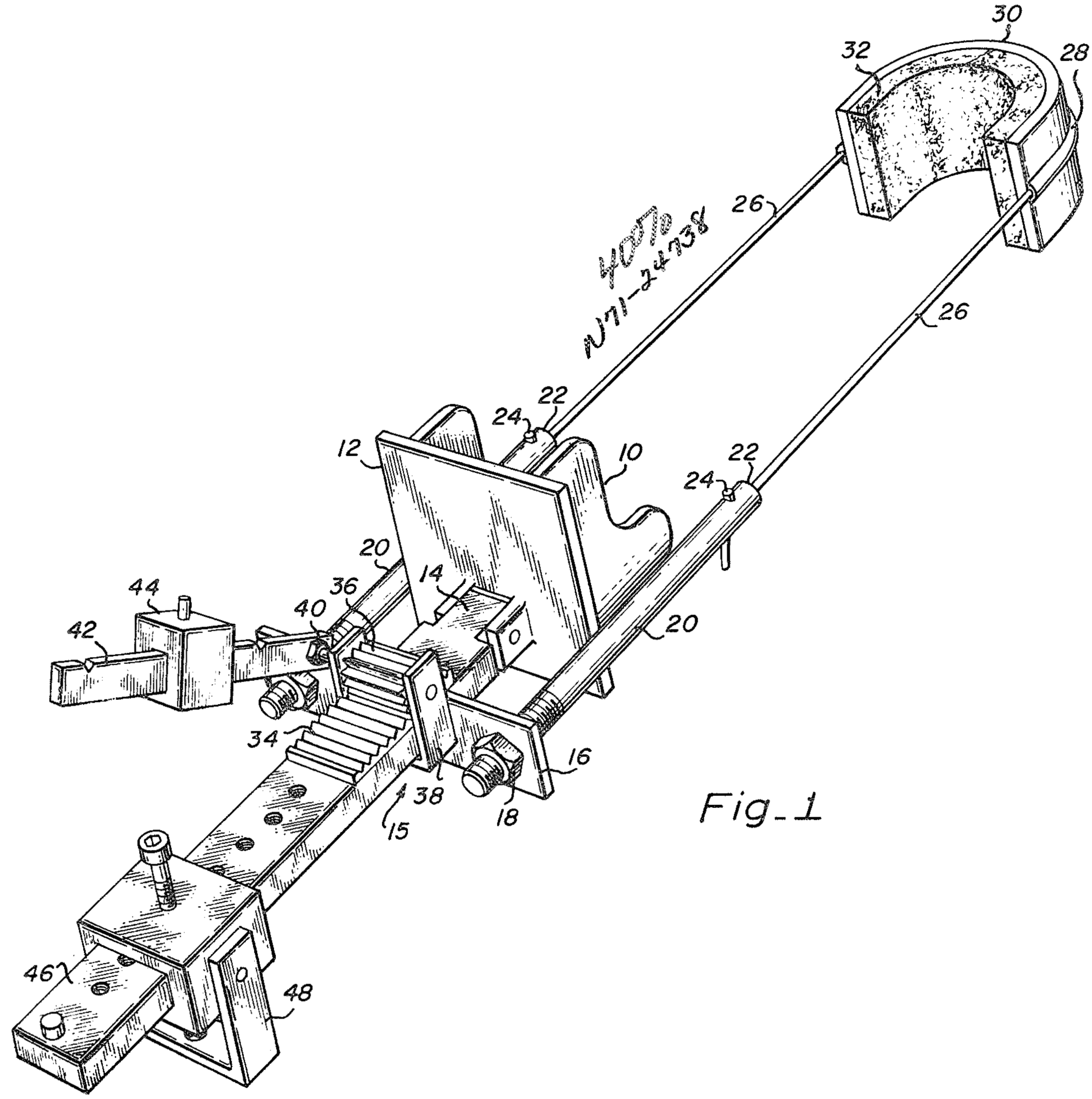

Fig_1

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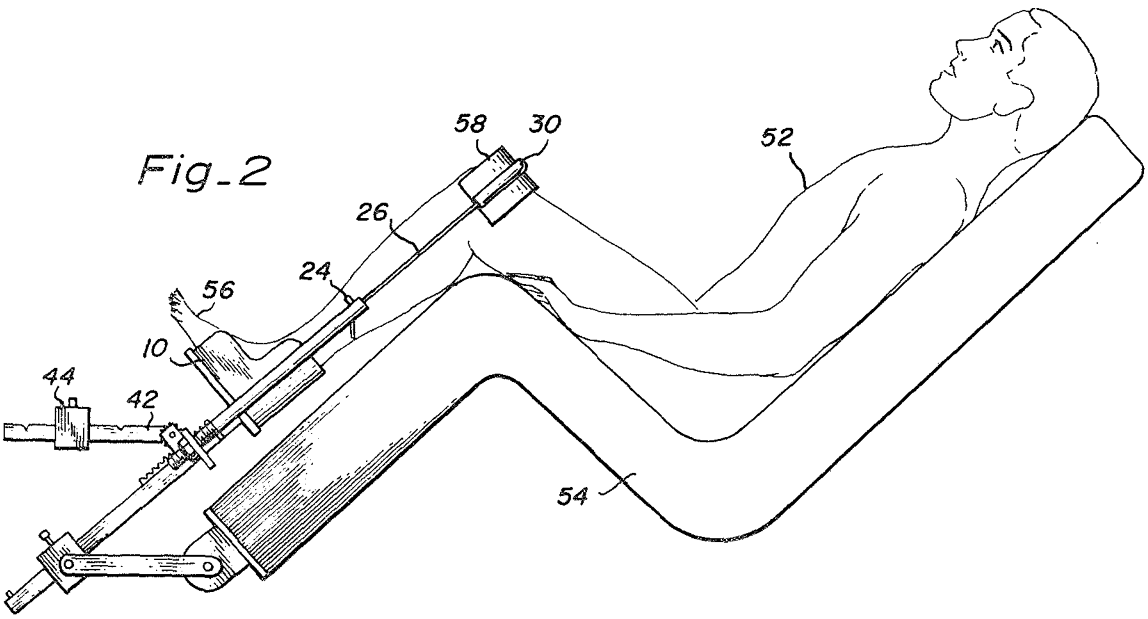

Fig_2

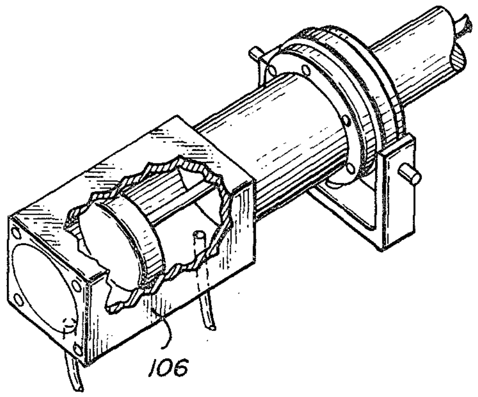

Fig_6

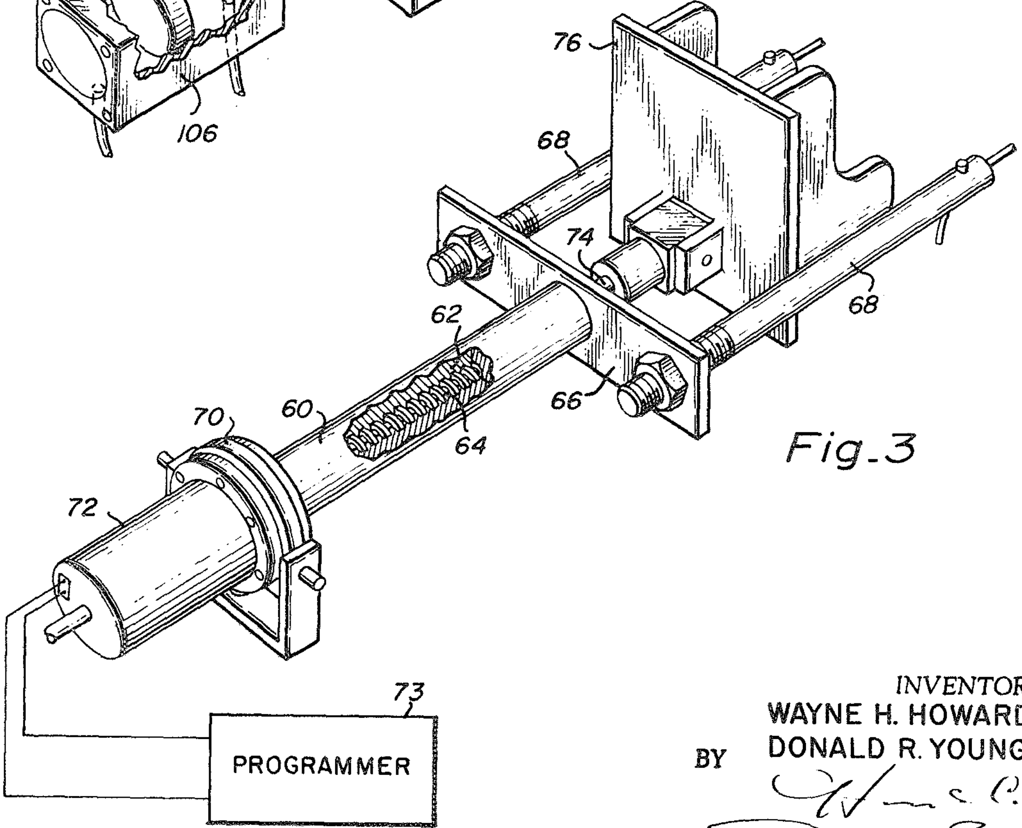

Fig_3

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Fig_4

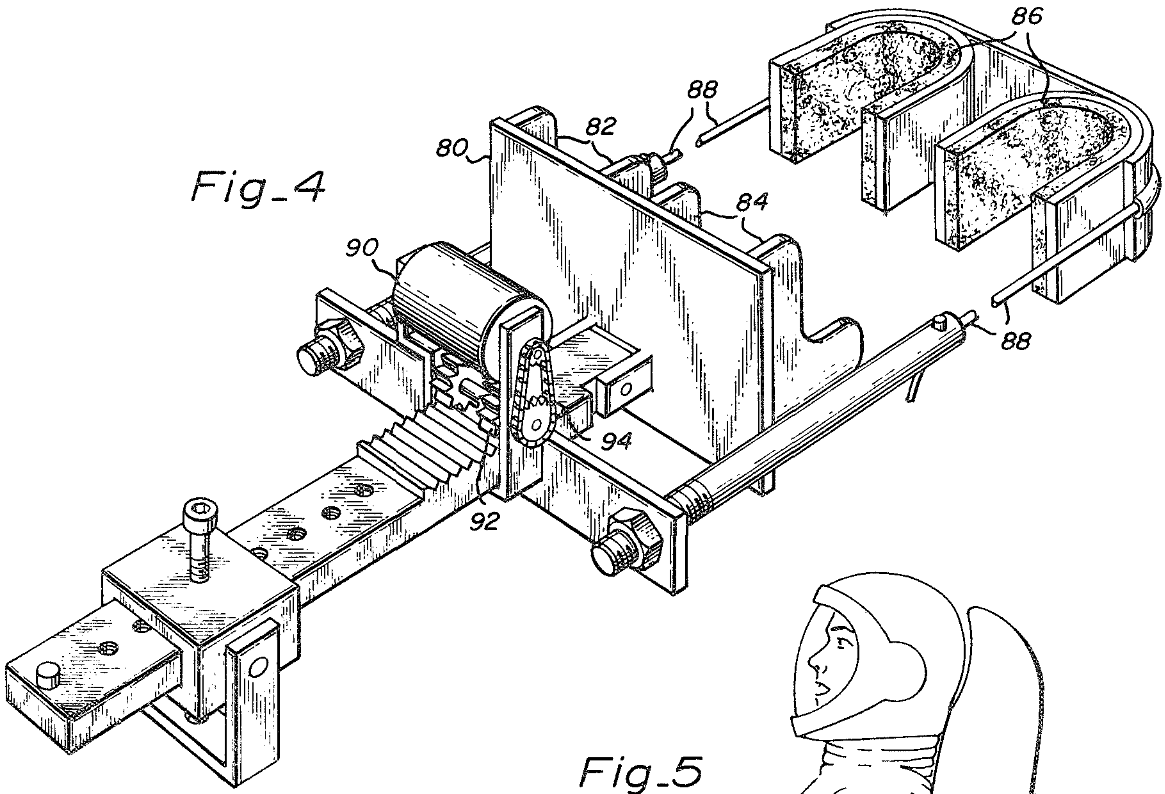
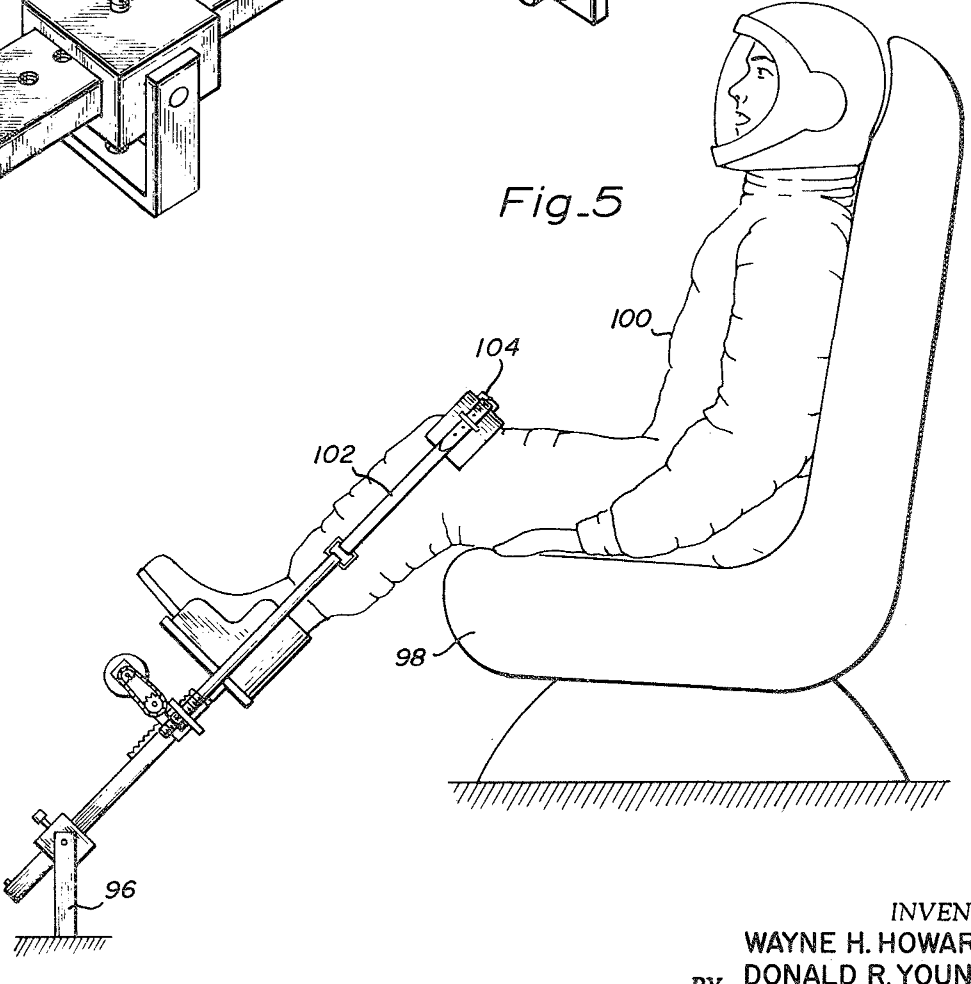


Fig_5



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United States Patent [11] **3,550,585**

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[22] Filed **Feb. 6, 1969**
[45] Patented **Dec. 29, 1970**
[73] Assignee **the United States of America as represented by the Administrator of the National Aeronautics and Space Administration**

[54] **SKELETAL STRESSING METHOD AND APPARATUS**
10 Claims, 6 Drawing Figs.

[52] **U.S. Cl.** **128/24,** 128/25
[51] **Int. Cl.** **A61h 1/00**
[50] **Field of Search** 128/24, 25, 75, 77, 78, 80

[56] **References Cited**
UNITED STATES PATENTS

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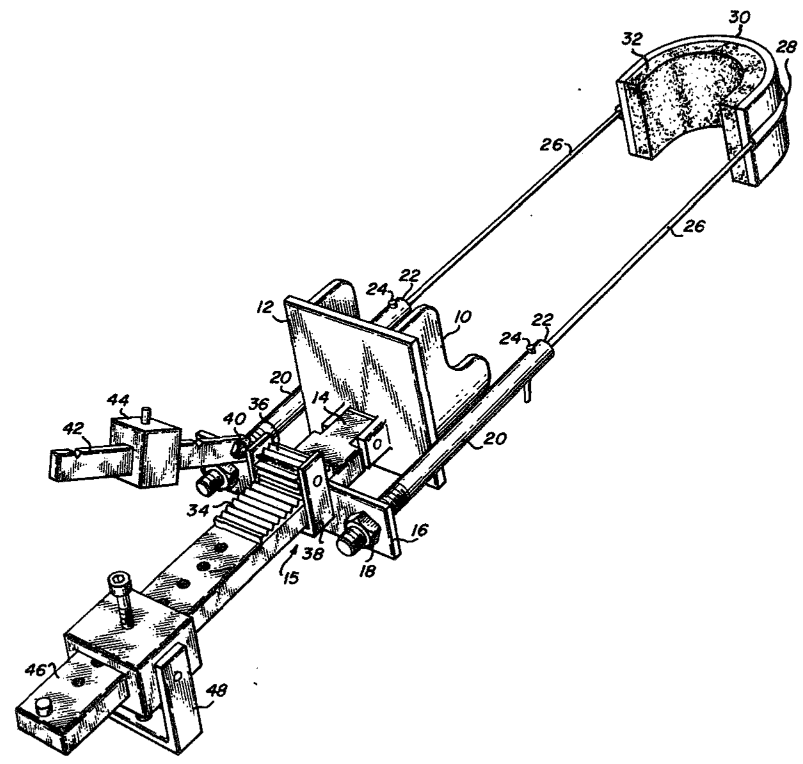
ABSTRACT: A method and apparatus for applying a predetermined force to the lower leg of a subject experiencing prolonged recumbency or weightlessness. The subject's foot is placed in a stirrup or shoe means which is connected directly to the rack of a rack and pinion apparatus. A knee plate is also connected to the rack and pinion device by suitable cable means or the like so that by applying a predetermined torque to the pinion a compressive force is applied to the lower leg of the subject between the ankle and knee so as to simulate the forces to which this portion of the leg is normally subjected during ambulation.



SKELETAL STRESSING METHOD AND APPARATUS

The invention described herein was made by employees of the United States Government and may be manufactured and used by or for the Government for governmental purposes without the payment of any royalties thereon or therefor.

BACKGROUND OF THE INVENTION

Increased bone resorption is a well documented consequence of prolonged bed rest and is strongly suspected of accompanying long periods of weightlessness. The experience gained in the manned space flight programs along with the experimental results obtained during various simulations of the weightless stage, indicate that loss of bone calcium may therefore be one of the acute problems associated with space flight. These tests have shown that the calcium loss is related directly to the absence of the normal stress of gravity acting upon the body in the upright ambulatory position. Since the likelihood of pathological fractures or renal calcinosis is great during conditions of bone calcium loss, it is quite important that preventative measures be taken to avoid the decalcification which is anticipated in reduced gravitational or inertial environments.

Although various types of exercise and physical therapy apparatus have been known and used for some time now, these devices have generally had as their principal object the exercitation of the muscles rather than the compressive stressing of the skeletal structure. Examples of such exercise apparatus can be found in U.S. Pat. Nos. 2,058,563, 2,689,127, 2,924,214, 2,855,199, 3,103,357, and 3,116,062. Although these devices appear to stress the skeletal structure as an indirect result of exercising the muscles, none are specifically directed toward applying longitudinally compressive forces to certain skeletal components in order to simulate the normal gravity loading thereof during normal standing or ambulatory maneuvers.

SUMMARY OF THE INVENTION

The present invention relates generally to bodily force applying methods and apparatus, and more particularly, to a method and apparatus for applying compressional forces to a portion of the skeletal structure of a subject so as to simulate the forces applied to that portion during normal ambulatory conditions in a gravitational environment.

Briefly, the apparatus of the present invention includes a means for applying a longitudinal force to the lower leg between the ankle and the knee. The foot is placed in a stirrup or shoe means which is connected to a knee plate through a rack and pinion device which draws the two together for applying to the lower leg a predetermined static or dynamic force over a selected period of time.

It is therefore a principal object of the present invention to provide a method and apparatus for applying to the lower leg, forces which simulate the longitudinal compressive loads normally encountered by the lower leg of a subject during ambulation in a gravitational environment.

Another object of the present invention is to provide a device of the type described which is relatively light weight, easy to maintain and operate, and which can be modified easily to fit various subject sizes so as to provide a minimum of discomfort.

Still another object of the present invention is to provide a means for applying longitudinal compressive forces to the lower leg of a subject which is subjected to a long period of recumbency or weightlessness, so as to minimize the calcium loss suffered during such periods.

Still another object of the present invention is to provide apparatus of the type described which is simple in construction and suitable for use in spacecraft and the like.

Still another object of the present invention is to provide hardware for applying forces to the skeletal system in the manner described, which allows moderate movement of the legs consistent with comfort during the application thereof, and which is capable of applying forces with a magnitude in the range of those to which the bones would normally be subjected during periods of ambulation in a gravity environment.

Still other objects and advantages of the present invention will be apparent from the following description of the preferred embodiment which makes reference to the several FIGS. of the drawings.

IN THE DRAWINGS

FIG. 1 is a perspective view of a leg force application device in accordance with the present invention.

FIG. 2 is a side elevation illustrating the use of the device of FIG. 1 by a bedridden patient.

FIG. 3 illustrates a modified embodiment of the apparatus as illustrated in FIG. 1.

FIG. 4 is a still further modification of a leg force application device in accordance with the present invention.

FIG. 5 illustrates the use of the device of FIG. 4 in a spacecraft or the like.

FIG. 6 illustrates a hydraulic force application mechanism in accordance with the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIG. 1 of the drawings, there is shown a force application device, in accordance with the present invention, for applying a predetermined force to the lower leg of a subject experiencing prolonged recumbency due to weightlessness or as a result of being bedridden. The apparatus as illustrated includes a shoe or stirrup means **10** for receiving the heel of the subject so as to align the lower leg generally normal to the force applying platform **12** which is attached to a force applying rack **14** of a rack and pinion means **15**. Fixedly secured to the pinion thereof and movable relative to rack **14** is a flange **16** extending laterally to either side of the platform **12**.

Secured to the flange means **16** by locknuts **18**, or the like, are a pair of compression bars **20**, one end of which is threaded to receive the locknuts **18** and the other end of which includes a cable receiving aperture **22** and cable locking setscrews **24**. Secured to the ends of the compression bars **20** by setscrews **24** are the ends of a cable **26**, which pass through a cable receiving conduit **28** in a padded knee plate **30**. The knee plate **30** consists of a generally U-shaped metal plate having a suitable pad **32** which is molded to generally conform to that portion of the subject's leg just above the knee.

Disposed on the upper surface of the rack **14** are a plurality of teeth **34** which are engaged by a pinion gear **36**, which is rotatably mounted to a U-shaped bracket **38** affixed to flange **16**. Attached to the shaft **40** of the pinion **36** is a weight-bar lever arm **42** having a weight **44** positionable along the length thereof for applying a selected torque to the pinion **36**, which in turn causes the pinion mounting means **38** and flange **16** to be biased in a direction away from the platform **12**. The cable **26** is thereby put in tension to apply a longitudinal compressive force to the lower leg of the subject whose knee is positioned in the knee plate **30** whose heel is positioned in the shoe **10**. In order to mount the apparatus so that the wearer's leg will be free to move within a comfortable degree of freedom, the end **46** of the rack **34** is secured to a mounting bracket **48** which can be fastened to a suitable base structure such as a bed, chair, floor or the like.

Turning now to FIG. 2 of the drawings, the apparatus illustrated in detail in FIG. 1 is shown in operation. A bedridden patient **52** is positioned in a generally recumbent position on a bed means **54** with his legs cocked slightly so that the knee can be received within the knee plate **30**. The apparatus is secured to the end of the bed by attaching the mounting means **48** thereto. It should be pointed out here that the complete apparatus may include two boot means **10** for receiving both feet simultaneously or in the alternative, two individual force applying devices can be used to accommodate each foot of the patient. A modified two-legged device will be described in detail below the reference to FIG. 4.

Once the foot **56** is placed in the boot **10** and the knee plate **30** is positioned above the knee **58** of the patient, the cables **26** are pulled taught and the setscrews **24** are tightened. With the pinion **36** suitably positioned and a suitable weight **44** is located appropriately along the lever arm **42** so as to apply the desired torque to the pinion **36**. The resultant torque causes a compressional force to be applied to the lower leg of the patient as the knee plate **30** is drawn towards the shoe **10**. Such a device will apply a continuous force to the leg, but will still allow a certain degree of movement of the leg by the patient.

In general, the force applied to the leg should be about equal to that which the leg would normally be subjected with the patient standing upright on a level surface. The period of application of the force will, of course, be varied with the patient's requirements and may either be applied continuously during predetermined daily periods or may be interrupted periodically as desired.

Alternatively, the device may be modified as shown in FIG. 3 so as to include means for periodically varying the force applied to the leg to simulate walking, running, or other leg load conditions to which the leg would normally be subjected. It should also be apparent that the rack and pinion illustrated in FIG. 1 could be replaced by a variable load spring means or other suitable apparatus for applying a continuous or variable force over a given period of time.

In FIG. 3 of the drawings, there is illustrated a modified form of the leg force applying apparatus of the present invention, which includes a servocontrolled jack-type force applying means **60**, which includes an internally threaded push-rod **62** into which the threaded shaft **63** is operatively received. One end of the push-rod **62** includes a flange means **70** to which a servomotor **72** is mounted. One end of the threaded shaft **64** is operatively driven by the servomotor **72** and the other end **74** is rotatably secured to the bottom of the force applying platform **76**.

In accordance with this embodiment of the invention, means are provided for continuously applying a predetermined force to the leg of the wearer in a manner similar to that in which the previously described embodiment was operated. Alternatively, a programmed control means **73** may be utilized to variably energize the servomotor **72** causing it to apply a predetermined variable force to the leg to simulate actual ambulatory movement by the patient.

Turning now to FIG. 4 of the drawings, a still further embodiment of the invention will be described. In this embodiment, the force applying plate **80** is made wide enough to accommodate two shoe means **82** and **84** for receiving both feet of the subject simultaneously. In accordance with this embodiment, two knee plates **86** are also provided for simultaneously receiving the tensile force supplied by the cable means **88** so as to apply longitudinal compressive forces to the lower legs of the subject.

In accordance with this embodiment of the invention, a servomotor **90** is provided in place of the weight and lever arm illustrated in FIG. 1. The servomotor **90** is mounted on the upper portion of the U-shaped bracket **91** which is carried by the pinion **92**. The servomotor **90** is driveably connected to the pinion **92** by means of a chain drive **94** or other suitable drive means. By applying a suitable control signal to the servomotor **90**, a desired force can be transmitted through the rack and pinion apparatus and associated force applying structure so that it is simultaneously applied to both legs of the subject wearing the device.

In FIG. 5, use of FIG. 4 embodiment in a spacecraft is illustrated. To illustrate one possible application, the mounting bracket **96** may be mounted to the floor of the craft in front of the seat **98** and in a position to receive the legs of the astronaut **100** when he is seated in the normal flight position. With the device so mounted, it could easily be rotated out of the way when not in use. In addition, the cable means **98** could be replaced by a belt means **102** or the like, which includes a quick-disconnect connector means **104** for facilitating rapid placement and removal of the device.

While many modifications of the present invention will be readily apparent to those skilled in the art, it is to be understood that the disclosed apparatus is for purposes of illustration only. As described above, the device provides hardware which can be used to apply longitudinal compressive forces to the lower leg of a subject or can be used as a laboratory-type device for allowing systematic evaluation of the effect of applied forces on the integrity of the skeletal system.

Although the particular apparatus disclosed relates to a lower leg force applying structure, it is to be understood that the inventive method also anticipates the application of similar forces to the other portions of the skeletal structure; for example, compressive forces applied to the upper leg between the knee and hip, or to both upper and lower leg by compressive application between the heel and hip.

The device, as disclosed, can be made of any suitable materials which are strong enough to support the applied forces. One preferable requirement, in so far as structure is concerned, is that the device be relatively lightweight and allow moderate movement of the subject's legs consistent with comfort. Furthermore, the device should be suitably configured so as to enable use by a subject assuming a variety of bodily positions. Although the described manner of applying the forces to the lower leg has been disclosed in the form of weights, servomotors or spring means, it is contemplated that many other types of lead imposing apparatus will become apparent to those skilled in the art. For example, the hydraulic force applying embodiment **106** of FIG. 6 could be substituted for the jack-type apparatus of FIG. 3.

The apparatus should be simple enough in construction and operation so that it can be easily fitted and removed from the subject either by the subject himself, or by an assistant, depending of course upon the particular application. The inherent simplicity of the apparatus renders it relatively maintenance free. So as to accommodate a particular use, all components are readily accessible to facilitate easy interchangeability of parts among several basic modifications.

Whereas many alterations and modifications of the present invention are contemplated, it is to be understood that the above-described embodiments are for illustrative purposes only and are not intended to be limiting in any way. Moreover, it is intended that the appended claims be interpreted as covering all alterations and modifications which fall within the true spirit and scope of the invention.

We claim:

1. An anatomical force applying apparatus for applying a compressive force to a particular portion of the skeletal structure of a subject comprising:
   - a first force applying member for engaging one extremity of the skeletal component which is to be subjected to a compressive force;
   - a second force applying member for applying a force to the other extremity of said skeletal component; and
   - loading means operatively coupling said first and second force applying members together, so that a predetermined compressive force can be applied to the skeletal component which is positioned between said first and second force applying members.

2. An anatomical force applying apparatus as recited in claim **1** wherein said first force applying member is a shoe means for receiving the foot of a subject in such a manner that the force applied thereby is transmitted to the bones of the lower leg of the subject.

3. An anatomical force applying apparatus as recited in claim **2** wherein said second force applying member is a knee plate for engaging the leg of the subject proximate the upper knee portion so that the skeletal component which is subjected to the compressive force is the lower leg.

4. An anatomical force applying apparatus as recited in claim **3** wherein said load means includes a rack and pinion means, the pinion of which is connected to one of said mem-

bers and the rack of which is connected to the other of said members such that when a torque is applied to said pinion said first force applying member is driven in a direction towards said second force applying member so as to apply a longitudinal compressive force to the bones of the lower leg of the subject.

5. An anatomical force applying apparatus as recited in claim 4 wherein said load means further includes a lever and weight means for applying a predetermined torque to said pinion.

6. An anatomical force applying apparatus as recited in claim 4 wherein a servomechanism is provided for applying a predetermined static or dynamic torque to said pinion so as to load the leg of the subject in a predetermined manner.

7. A method for reducing the calcium loss in an animal being due to long periods of recumbency or weightlessness comprising applying a compressive force to a portion of the skeletal structure of said being in a manner so as to simulate normal bone load conditions during ambulation in a gravity environment.

8. A method for reducing the calcium loss in an animal being as recited in claim 7 further including the step of varying the compressive force applied to the skeletal portion in accordance with a predescribed manner.

9. A method for reducing the calcium loss in an animal being in accordance with claim 8 wherein said compressive force is applied to the lower leg of the subject between the ankle and the knee and said force is directed along the longitudinal axis of that portion of the leg.

10. A method for reducing the calcium loss in an animal being as recited in claim 9 wherein the force applied to said leg is programmed so as to simulate actual ambulatory leg load conditions due to the weight of the subject.