July 4, 1967 N. A. MacLEOD 3,329,142

MEANS AND METHOD FOR EXERCISING JOINTS AND IMPROVING BLOOD AND LYMPH CIRCULATION THEREIN

Filed June 21, 1963 2 Sheets-Sheet 1

Fig. 1.

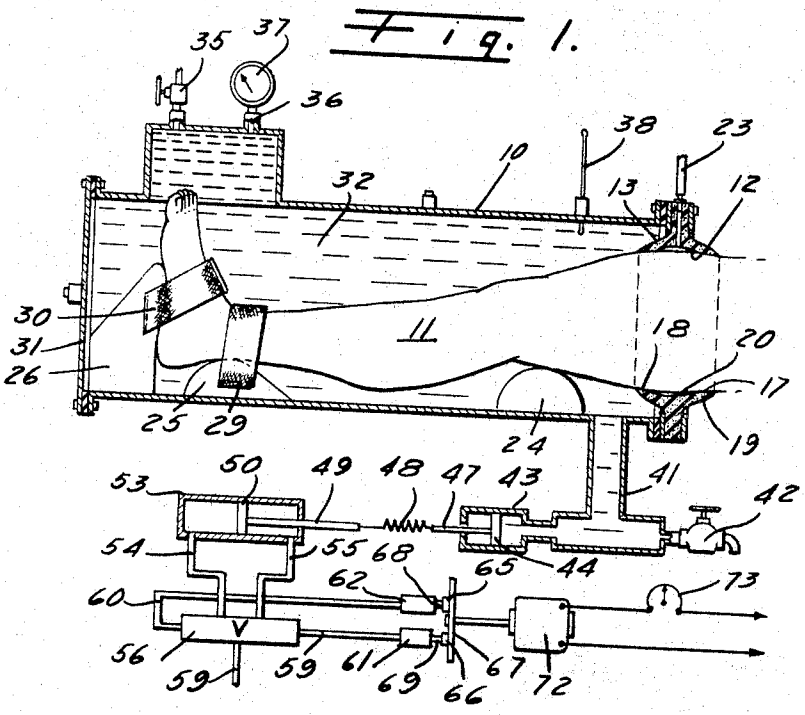
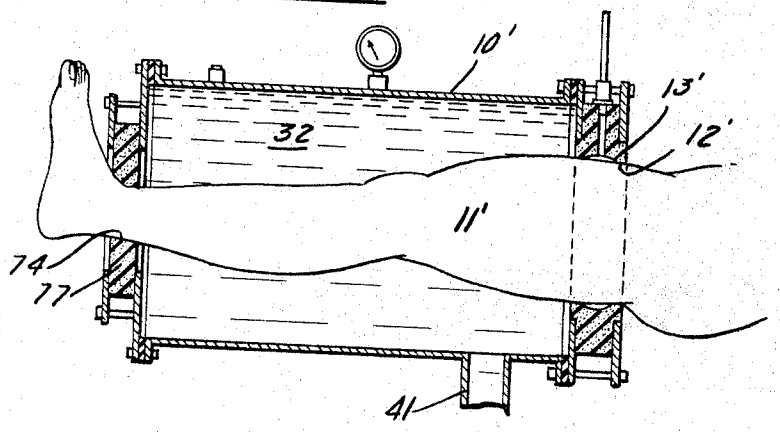


Fig. 2.



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Filed June 21, 1963 2 Sheets-Sheet 2

Fig. 3.

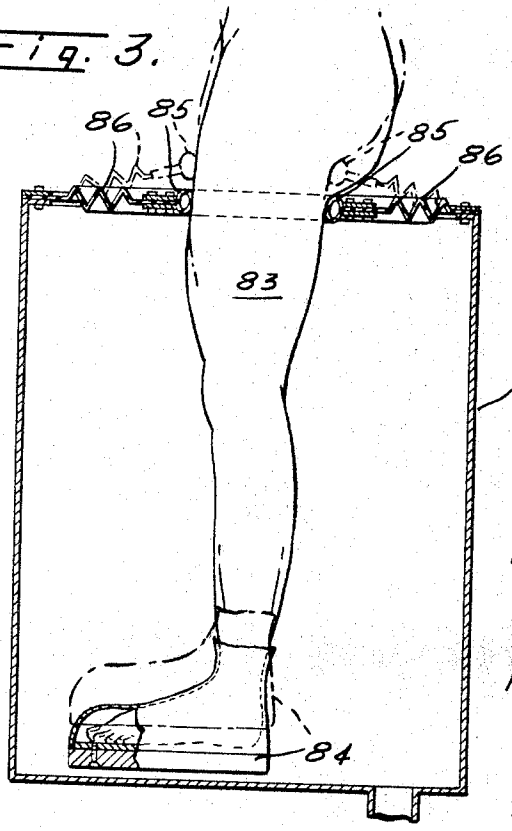


Fig. 6.

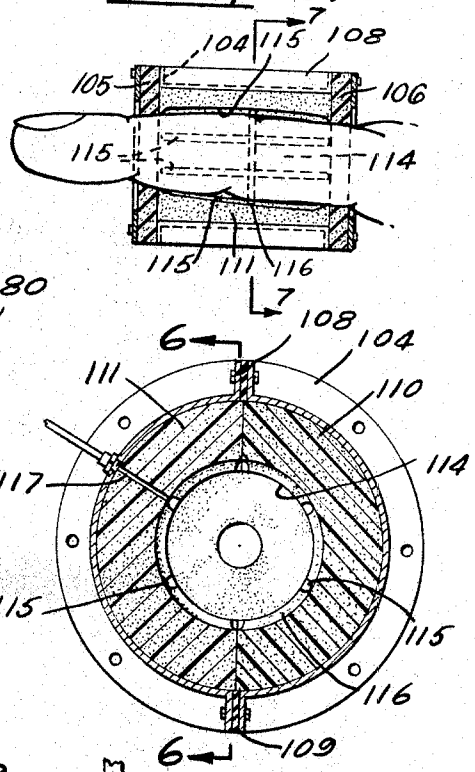


Fig. 7.

Fig. 4.

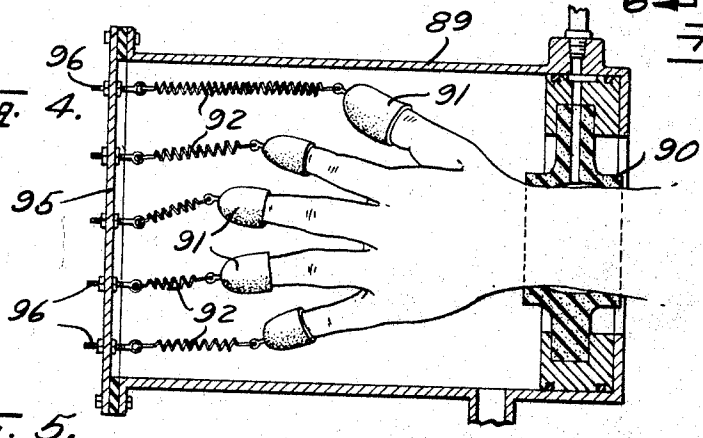
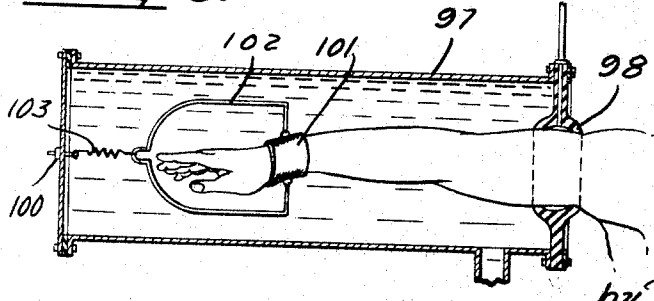


Fig. 5.



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United States Patent Office 3,329,142
Patented July 4, 1967

3,329,142

MEANS AND METHOD FOR EXERCISING JOINTS AND IMPROVING BLOOD AND LYMPH CIRCULATION THEREIN

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Filed June 21, 1963, Ser. No. 289,655
12 Claims. (Cl. 128—40)

This is a co-pending application of one which issued as United States Patent No. 3,094,983 for Blood Circulation Device and Method on June 25, 1963.

This invention relates to a method and apparatus for causing movements of joints in arms, legs, fingers and toes, and more particularly, is related to a method and means for exercising the joints in combination with improving the blood and lymph circulation in and around the joints.

I have found in the practice of the invention, described in my above patent that an arm or leg being treated in a liquid-filled variable pressure chamber is forced outwardly and inwardly with the application of alternate positive and negative pressures to all of the liquid in the chamber. This movement has amounted to one inch or more and its extent is dependent upon the volume of the piston displacement used to vary the pressure of all the liquid in the chamber.

It has been found that even with a relatively inflexible sealing means, the sealing means being around a limb in the chamber filled with liquid so as to prevent leakage around the limb in the chamber opening, that the limb moves even if the epidermis is almost stationary. This movement is due to the plastic deformable nature of muscle, and fatty and other tissue beneath the epidermis and surrounding the bone. Thus, if a joint is encased in a variable pressure chamber, according to this invention, there are compression and tension stresses on the joint during negative and positive pressures within the chamber, respectively, due to the inertia of the tissue and bone and the unavoidable movement of the encased limb when the pressure in the chamber fluctuates.

It is an object of the present invention to provide a method and apparatus for exercising joints.

It is another object of the present invention to provide an improved method and improved apparatus for tensing and compressing a joint.

It is still another object of the present invention to provide a method and apparatus to apply tension and compression to a joint by means of pressure changes around the joint.

It is a further object of the present invention to provide a method and apparatus for exercising joints and for simultaneously improving the blood and lymph circulation in and around the joints.

It is a still further object of the present invention to provide a method and apparatus by which pressure variation is used to produce deep tissue influences involving inter-tissue movement and extension and contraction of limbs or digits of the human body or animals.

It is another object of the present invention to provide a method and apparatus by which pressure variation is used to produce rapid extension and slow contraction of limbs, or vice versa, causing the working of joints and the stimulation of the blood and lymph flow around the joints.

It is still another object of the present invention to provide a method and apparatus for treating rheumatoid arthritis and other afflictions which are specific to the joints of the human body or animals.

Further objects and advantages of the invention may

be brought out in the following part of the specification wherein small details have been described for the competence of disclosure, without intending to limit the scope of the invention which is set forth in the appended claims.

Referring to the accompanying drawings, which are for illustrative purposes only:

FIG. 1 is a side elevational view, partially in cross section, of an apparatus according to the present invention;

FIG. 2 is a cross sectional view of another embodiment of the present invention;

FIG. 3 is a side elevational view of a chamber according to the invention, in which a weighted leg is in position for treatment;

FIG. 4 is a view of a chamber according to the invention and which is specifically designed for the treatment of the fingers and hand;

FIG. 5 is a view of an embodiment of the invention specifically designed for the treatment of the wrist and arm;

FIG. 6 is a fragmentary, cross sectional view of an embodiment of the invention in which a gas can be used as the fluid, and taken as indicated by the line **6—6** of FIG. 7; and

FIG. 7 is a cross sectional view, taken as indicated by line **7—7** of FIG. 6.

Referring again to the drawings, in FIG. 1, there is shown an elongated pressure chamber **10**, having a cross section suitable to receive a human leg **11** and having an open end **12** into which the leg has been inserted. Within the open end, there is a seal **13**, having its outer periphery secured to a flange of the chamber and having its inner periphery **17** substantially annular to conform to the leg **11**. The inner periphery of the seal has two lips **18** and **19**, spaced by an enlarged diameter surface **20**. The seal is maintained by a negative pressure made available through a tube **23**, terminating inwardly through the surface **20** so that the negative pressure draws the skin of the leg against the surfaces of the lips **18** and **19** and toward the surface **20**, a greater pressure at all times being exerted on the exterior surfaces of the seal to force it into sealing relationship with the leg.

The leg shown to be resting within the chamber **10** on hard rubber cushions **24**, **25** and **26**, the cushions being secured to the chamber. The leg is secured at the ankle to the cushion **25** by a strap **29** and the foot is secured to the cushion **26** by a strap **30**, the straps being so secured through access flange **31**.

The chamber **10** is adapted to be completely filled with a liquid **32**, such as water, as disclosed in the above-mentioned co-pending application. It may be filled through a fitting **35**, and vented, while filling, through a fitting **36** to which a pressure gauge **37** is attached after the chamber is completely filled, as shown. A theremometer **38** is sealingly secured in the chamber for use with treatments where it is desirable to regulate the temperature of the liquid.

Extending downwardly from the chamber **10** is a pipe **41** connected to a drain valve **42**, used to drain the chamber, after a treatment, for example, prior to the time the limb is removed. Also connected to the pipe **41** is a cylinder **43**, having a reciprocating piston **44** slidably and sealingly engaged therein. When the chamber is filled with liquid for treatment purposes, that part of the cylinder **43** to the right of the piston in the drawing is also always filled with the liquid so that any movement of the piston in the cylinder changes the pressure in all of the liquid in the chamber and the pressure on the limb being treated.

The piston **44** has a rod **47** connected to a relatively stiff coil spring **48** which in turn is connected to a rod **49** of a compressed-air driven piston **50**. The piston **50** is slidably engaged to reciprocate in cylinder **53** and moves

in the direction of the air supply through conduits **54** and **55**, the air supply being directed to either conduit by means of a conventional compressed-air operated slide valve **56**. The compressed air is supplied to the valve **56** from a source **59** attached to a compressor. Connected to the valve **56** are air lines **59** and **60**, respectively connected to air discharge valves **61** and **62**. When air is discharged from one of the latter valves, the slide valve **56** is caused to reverse and direct the flow of air from one side of piston **50** to the other so as to reverse the direction of its movement. The air valves **61** and **62** are actuated to discharge air by means of knobs **65** and **66** projecting from a motor driven disc **67**. As the disc rotates, the knobs make contact with spring-loaded poppets **68** and **69**, the latter being moved inwardly in the respective valves against the force of their springs on contact with the respective knobs **65** and **66**. That is, when one of the poppets **68** or **69** is contacted, its valve discharges so as to reverse the direction of the slide valve **56**.

The disc **67** has a multiplicity of holes therein concentrically located so that the knobs **65** and **66** can be positioned to determine the cycle of the pistons **50** and **44** and thus, the cycle of the pressure within the chamber **10**. The disc **67** is driven by a variable speed motor **72**, the speed being regulated by a rheostat **73** which determines the frequency of the pressure cycle in the chamber **10**.

In operation, when the piston **50** is moved to the right in FIG. 1, the spring **48**, being relatively stiff, acts as a compression spring to move the piston **44** to the right to increase the pressure within the chamber **10**, the amount of increase being dependent upon the volume of fluid moved by the piston **44** which is dependent in part upon the length of the positive pressure cycle. When the cycle is reversed, the piston **50** moves to the left and the spring **48** acts as a tension spring to draw the piston **44** to the left to apply a lesser positive pressure or a negative pressure to the chamber **10**.

As the foot of the leg **11** is held in position by the straps, any fluctuation of pressure in the chamber causes a movement of the thigh, toward or away from the foot, depending upon whether the pressure pulse is positive or negative. During the cycle, the ankle and knee joints are worked, while at the same time the pressure fluctuation helps circulation in the limb generally.

By changing the nature of the pressure rise and fall and also the rate of cycling, any desired jigging action can be attained. A one-pound per square inch increase or decrease in pressure applied to the leg, which is free to move inwardly or outwardly of the cylinder under the constraint of the seal, provides an impulse which is determinable by a formula $PxAxT$, where P equals pressure per square inch, A equals the area of the thigh at the seal, and T equals the time in seconds. Thus, for a one-pound per square inch pressure difference applied to a thigh having an average diameter of seven inches, and during a period of one tenth of a second, the impulse on the leg will be

$$1 \times \frac{\pi \times 7 \times 7}{4} \times \frac{1}{10}$$

or 3.85 pound-seconds. For a two-pound per square inch pressure fluctuation, this would be doubled, and for a three-pound per square inch pressure fluctuation, the impulse would be tripled, and so on.

If the pressure fluctuation cycle is of one-second duration, then, with an average of one-pound per square inch of positive and of negative pressure during each half second, the total impulse in each direction, that is, to and from the knee and ankle in FIG. 1, is $3.85 \times 5 \times 3600$ or 69,300 pound-seconds of impulse per hour, which provides a great amount of exercise and circulation stimulus to the leg. The movement of the leg can easily be one inch or more and is dependent upon the volume of the displacement by the piston **44**. Further, even the joints outside the chamber, as in this case, the hip joint, is exercised by the tension and compression forces on the leg and therapeutic benefits to the hip result.

In FIG. 2, there is shown a chamber **10'** having a seal **13'**, equivalent to that in FIG. 1, at an open end **12'**. The other end of the chamber also has an open end **74** surrounded by a generally annular, elastomeric seal **77** sealingly engaged with an ankle of a leg **11'**, the seal **13'** being sealingly engaged with the thigh. The remainder of the chamber and the pressure producing apparatus, to act upon the liquid **32** and the leg **11'**, is the same as that shown in FIG. 1.

In the embodiment in FIG. 2, the intention is to only exercise the knee, and the ankle and thigh are restrained by the seals **13'** and **77**. The actual impulse to the leg is determined by the pressure pulse in the chamber and by the area of the smallest part of the limb which is within the seal **77**. For example, on a rise in pressure, the thigh will tend to move out of the chamber, and will so move slightly, but the movement outward is retarded by the tendency of the ankle to move outwardly also.

In this situation, the impulse to the knee joint is $PxAxT$, where A is the area of the ankle at the sealing point. As ankles have average diameters of only about three inches, or less than half of the average of thigh diameters, the impulse to the leg is only about one-quarter of that when the ankle is held rigidly, as in FIG. 1.

The two-collar seal arrangement in FIG. 2 provides a higher impulse efficiency when it is used on a wrist and upper arm or between two parts of a finger where the relative differences of areas are much smaller than those of an ankle and thigh.

A suitably designed chamber, similar to that in FIG. 2, can be designed for use above the shoulder and below the elbow to exercise both the shoulder and the elbow. Similarly, a chamber having seals adaptable to be placed around the lower abdomen and the thigh of each leg could be used to exercise the hip joints with the concomitant stimulation to bloo dand lymph circulation.

In FIG. 3, there is shown a chamber **80** adapted to have the pressure of liquid therein varied in the same manner as the chamber shown in FIG. 1. The chamber **80** is adapted to receive a leg **83** vertically as it hangs from the body and is unsupported at the foot. A heavy, weighted shoe **84** is secured to the foot to tend to hold the leg downwardly near the bottom end of the chamber. At the upper, open end of the chamber is a generally annular, elastomeric seal **85** supported by a flexible corrugated member **86**.

As the pressure is increased in the chamber **80**, the leg is forced upwardly and the weighted shoe tends to hold it downwardly so as to particularly exercise the knee and to generally exercise the ankle and thigh. As the pressure in the chamber is reduced or made negative, it acts upon the leg to pull it downwardly and the weight on the foot gives the leg an extra pull to better exercise the knee.

In FIG. 4, there is shown a chamber **89** in which the pressure of all of the liquid may be varied from positive to negative in cycles particularly adapted for exercising the fingers, hand and wrist, and for stimulating the circulation of the blood and lymph therein. A negative pressure seal **90** surrounds the wrist and tends to secure it in the chamber, and on each of the ends of the fingers is secured an elastomeric cap or finger **91** having its outer ends secured to a spring **92**, which in turn is adjustably secured to a flange **95** by means of an I-bolt **96**. Thus, each of the springs **92** on the fingers may be pulled so as to tension the fingers in a position of rest. Then, as the pressure is increased on the liquid in the chamber, the joints in the fingers and the wrist are pulled and when the negative pressure is applied, the springs act to return the fingers and the wrist toward the flange **95**.

In FIG. 5, there is a chamber **97** particularly designed to exercise the elbow. The upper arm is secured in a seal **98** at the open end of the chamber and the wrist is secured in a strap **101**, in turn supported by a generally

U-shaped frame **102** having its outer end secured to a spring **103**. The latter is adjustably secured by means of an I-bolt **100**. Here again, the arm is held in a position of rest toward the closed end of the chambers and it is moved and exercised in accordance with the negative and positive pressure pulses to the liquid.

In FIGS. 6 and 7, there is shown an open-ended chamber **104** formed of two half cylinders secured together at their flanges, generally designated **108** and **109**. An elastomeric seal **105** is adjacent the end of a finger, the seal being formed by the resiliency of the material, and at the other end of the chamber, there is a suction-type seal **106**, as shown in FIG. 1. Within the chamber, there are two elastomeric members **110** and **111** which, when placed together, form a tube having an inner cylindrical opening **114** of a diameter to receive the finger, with portions thereof extending outwardly of the chamber. The surface of the cylindrical opening **114** has elongated recesses or slots **115** and an annular groove **116**. The slots **115** and the groove **116** provide a gas flow path to the cylinder **114** and to the finger from a radially directed tube **117** which is connected to a gas varying pressure source, such as an enlarged version of piston **44** in FIG. 1.

The piston to vary the pressure of the gas in the cylinder **114** and on the finger has to be somewhat larger, relatively, because of the compressibility of the gas in contrast to the non-compressibility of the liquid as used in chamber **10** in FIG. 1. However, since the volume of the gas surrounding the finger is very small, the amount of gas which can be compressed or expanded around the finger is also very small.

A gas, of course, has a disadvantage, in contrast to a liquid, in that it is compressible, but when the gas is restricted to a very small volume, there is very little gas to be compressed or expanded and the pressure can be adequately applied to a limb with air as the medium in such low volume situations. If there should be an excess of space between a finger, as in this case, and the chamber surfaces, a non-porous plastic material can be inserted to reduce the air volume. However, with air as the medium to apply the pressure variations to a limb or finger, the pressure-time curve cannot be steep and the cycling of the pressure variation cannot be as fast as with liquid. A gas or air has one advantage over liquid and that is that it does not have to be drained away or handled.

In the embodiment of the invention shown in FIGS. 6 and 7, as the positive pressure pulse is applied to the finger and the chamber by the air medium, the joint of the finger is put into tension and the finger tends to move outwardly of the chamber at both ends. Similarly, when the negative pressure pulse is applied, the joint of the finger is compressed and the finger is moved inwardly into the chamber from both ends. This exercises the joint and stimulates the circulation of the blood and lymph in the finger.

It should be noted that while positive pressures of any desired amount can be readily applied to an enclosed joint, the amount of negative pressure which can be applied is limited by the atmospheric pressure at the time. However, the negative pressure can be increased by enclosing the entire body in a pressurized room as described in the above-mentioned patent. Similarly, in treating a finger joint or a knee, according to the method illustrated in FIG. 2 and FIG. 6, to increase the possible negative pressure applied, the entire limb can be enclosed in a surrounding chamber which can be pressurized to any required constant state.

The invention and its attendant advantages will be understood from the foregoing description and it will be apparent that various changes may be made in the form, construction and arrangement of the parts of the invention without departing from the spirit and scope thereof or sacrificing its material advantages, the arrangement hereinbefore described being merely by way of example. I do not wish to be restricted to the specific form shown or uses mentioned, except as defined in the accompanying claims, wherein various portions have been separated for clarity of reading and not for emphasis.

I claim:

1. A method for exercising joints and improved blood circulation adjacent thereto, comprising:
(a) enclosing a joint in a chamber;
(b) sealing said joint within said chamber;
(c) filling said sealed chamber with a liquid;
(d) applying a positive pressure to all of said liquid in said chamber to tense said joint; and
(e) applying a negative pressure to all of said liquid in said chamber to compress said joint.

2. A method for exercising joints and improving blood circulation adajacent thereto, comprising:
(a) enclosing a joint in a chamber;
(b) sealing said joint within said chamber;
(c) filling said sealed chamber with a liquid; and
(d) varying the pressure of all of said liquid to alternately tense and compress said joint.

3. A method for exercising joints and improving blood circulation adjacent thereto, comprising:
(a) enclosing a limb portion and a joint thereof in a chamber;
(b) securing one end of said limb within said chamber;
(c) sealing said limb adjacent to its other end within said chamber;
(d) filling said sealed chamber with liquid; and
(e) varying the pressure of all of said liquid to alternately tense and compress said joint.

4. A method for exercising joints and improving blood circulation adjacent thereto, comprising:
(a) enclosing a limb portion and a joint thereof in a chamber, said limb hanging vertically therein;
(b) attaching a weight to the lower and inner end of said limb adjacent the inner end of said chamber;
(c) resiliently sealing said limb within said chamber;
(d) filling said sealed chamber with a liquid; and
(e) varying the pressure of all of said liquid to alternately tense and compress said joint.

5. A method for exercising joints and improving blood criculation adjacent thereto, comprising:
(a) enclosing a limb portion and a joint thereon in a chamber;
(b) resiliently attaching one end of said portion to the inner end of said chamber;
(c) sealing said limb within said chamber;
(d) filling said sealed chamber with a liquid; and
(e) varying the pressure of all of said liquid to alternately tense and compress said joint.

6. A method for exercising joints and improving blood criculation adjacent thereto, comprising:
(a) enclosing a limb portion and a joint thereon in a chamber;
(b) extending portions of said limb outwardly of each end of said chamber;
(c) sealing the ends of said chamber on said limb portions;
(d) filling said sealed chamber with a liquid; and
(e) varying the pressure of all of said liquid to alternately tense and compress said joint.

7. A method for exercising joints and improving blood circulation adjacent thereto, comprising:
(a) enclosing a part of a body and a joint thereon in a chamber;
(b) said chamber conforming to the shape of said part therein and the interior surfaces of said chamber being in juxtaposition with corresponding surfaces of said part to provide a minimum space between said respective surfaces, said minimum of space being provided by gas passages along said interior surfaces and along said surfaces of said part;
(c) sealing said part in said chamber;
(d) filling said chamber with a gas;

(e) applying a positive pressure to all of said gas in said chamber to tense said joint; and

(f) applying a negative pressure to all of said gas in said chamber to compress said joint.

8. The combination of a variable liquid pressure device for exercising joints and means for improving blood and lymph circulation around the joints, comprising:

(a) a chamber for containing a liquid under pressure and means to fill said chamber with liquid;

(b) said chamber having an opening adapted to receive a part of a body having a joint therein;

(c) means to secure a portion of said part within said chamber;

(d) a seal being formable at said opening in contact with said body to close said chamber; and

(e) means to vary the pressure of all the liquid in the filled chamber so as to exercise the joints by tensing and compressing it.

9. The combination of a variable fluid pressure device for exercising joints and means for improving blood and lymph circulation around the joints, comprising:

(a) a chamber for containing a liquid under pressure and means to fill said chamber with liquid,

(b) said chamber having an opening adapted to receive a part of a body having a joint therein;

(c) means to adjustably secure the inner end of said part adjacent the inner end of said chamber;

(d) a seal being formable at said opening in contact with said body to close said chamber; and

(e) means to vary the pressure of all the liquid in the filled chamber so as to exercise the joint.

10. The combination of a variable fluid pressure device for exercising joints and means for improving blood and lymph circulation around the joints, comprising:

(a) a chamber for containing a liquid under pressure and means to fill said chamber with liquid,

(b) said chamber having an opening adapted to receive a part of a body having a joint therein;

(c) means to hold the inner end of said part adjacent the inner end of said chamber;

(d) a seal being formable at said opening in contact with said body to close said chamber; and

(e) means to vary the pressure of all the liquid in the filled chamber so as to exercise the joint.

11. The combination of a variable fluid pressure device for exercising joints and means for improving blood and lymph circulation around the joints, comprising:

(a) an open-ended chamber for containing a liquid under pressure and means to fill said chamber with liquid,

(b) said chamber being adapted to receive a limb having a joint therein and being adapted to have parts of the limb extending out of open ends;

(c) a seal formable at each of said open ends in contact with said limb to close said chamber; and

(d) means to vary the pressure of all the liquid in the filled chamber so as to exercise the joint by tensing and compressing it.

12. The combination of a variable fluid pressure device for exercising joints and means for improving blood and lymph circulation around the joints, comprising:

(a) a chamber for containing a liquid under pressure and means to fill said chamber with liquid,

(b) said chamber having an opening adapted to receive a part of a body having a joint therein;

(c) means to resiliently and adjustably secure the inner end of said part adjacent the inner end of said chamber;

(d) a seal being formable at said opening in contact with said body to close said chamber; and

(e) means to vary the pressure of all of the liquid in the chamber filled so as to exercise the joint by tensing and compressing it.

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