An exercise device, especially suitable for zero gravity workouts, has a collapsible chamber which generates negative pressure on the lower portion of a body situated therein. The negative pressure is generated by virtue of leg, hand and shoulder interaction which contracts and expands the chamber about the person and by virtue of air flow regulation by valve action.
SELF-GENERATING OSCILLATING PRESSURE EXERCISE DEVICE

ORIGIN OF THE INVENTION

The invention described herein was made in the performance of work under a NASA contract and is subject to the provisions of Section 305 of the National Aeronautics and Space Act of 1958, Public Law 85-568 (72 Stat. 426; 42 U.S.C. 2457).

FIELD OF THE INVENTION

The present invention relates generally to the field of exercise equipment and, more specifically, to a self-generating oscillating pressure exercise device suitable for use in normal, low or zero gravity environments.

BACKGROUND OF THE INVENTION

Deconditioning of musculoskeletal and cardiovascular systems occurs when there is a lack of gravitational load on the body during space flight. If conditioning exercise is not undertaken in such situations, substantial health problems will eventually ensue upon return to normal Earth gravity. Exercising in zero gravity poses many problems as most conventional exercise equipment and the exercises themselves are either dependent upon gravity or are limited to conditioning one set of muscles. What is needed for zero gravity exercise is a simple, self-powered device which is not dependent upon gravity and which provides simultaneous, integrated musculoskeletal and cardiovascular stimulation.

To effectively simulate exercise in Earth gravity, the device should impose pressure gradients across walls of blood vessels in the working muscle, especially in the lower body. Furthermore, externally-imposed pressure oscillations can facilitate blood flow to working muscle.

A self-generated pressure oscillating device which is worn by the user to exercise face muscles. A FIG. 1 shows a perspective view, partially cut-away, of an exercising device. The device, disclosed in the 141 patent, is strictly external and does not affect pressure applied to the user's body.

An object of the present invention is to provide an exercise device which is effective in normal, low or zero gravity conditions.

Another object of the present invention is to provide an exercise device capable of providing external pressure oscillations on the user's body which can facilitate blood flow to the exercising muscles.

Still another object of the invention is to provide an exercise device which is light weight, collapsible and thus easy to store, and simple in construction and operation.

These and other objects are met by providing an exercise device which includes first and second substantially rigid end walls, a flexible, variable length sidewall extending between and hermetically connected to the first and second end walls to define an air chamber having a variable volume, the air chamber being adapted to enclose at least a portion of a user's body and having an internal air pressure which varies in accordance with variations in volume, the side-wall being expandable and contractible in length to thereby vary the internal pressure in response to a force applied to one of the first and second end walls by the user, the applied force generating a reaction force delivered to the other of the first and second end walls and the applied force being resisted by a pneumatic force generated by a difference between the internal air pressure of the air chamber and ambient air pressure outside the air chamber.

Other objects, advantages and salient features of the invention will become apparent from the following detailed description, which taken in conjunction with the annexed drawings, discloses preferred embodiments of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view, partially cut-away, of an exercise device according to the present invention in a substantially expanded condition, with the user in a standing position;

FIG. 2 is a perspective view of the exercise device of FIG. 1 in a contracted condition, with the user in a knees-bent position;

FIG. 3 is a perspective view of the exercise device of FIG. 1 in the collapsed condition suitable for storage; and

FIG. 4 is a cross-sectional view of the exercise device of FIG. 1, taken along line 4-4 of FIG. 3.
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DETAILED DESCRIPTION OF THE INVENTION

Referring to FIGS. 1-4, an exercise device 10 includes a first substantially rigid end wall 12, a second substantially rigid end wall 14, and a flexible, variable length sidewall 16 disposed between and hermetically connected to the first and second end walls 12 and 14. Preferably, the end walls are circular in shape and together with the sidewall 16 define a cylindrical air chamber 18 which encloses at least a portion of the user's body.

The sidewall 16, which is expandable and contractible in length, is made of a rubberized canvas or other suitable airtight flexible fabric connected to a coiled wire support. In the preferred embodiment, the legs of the user are enclosed and the air chamber contracts when force is applied to the second end wall 14 as when the user performs knee bends. The user is illustrated in a knee-bent position in FIG. 2, and in an upright position in FIG. 1.

The second end wall 14 has a large center opening which is fitted with an elastic collar 20. An upper circumferential edge 22 of the collar frictionally engages the torso of the user to seal the user's legs within the air chamber 18. The collar 20 is made of the type of material used in kayakskins.

An opening 24 is formed in the second end wall 14 to provide fluid communication between the air chamber 18 and the ambient air outside the air chamber 18. A valve 26 pivotally connected to the upper surface of the end wall 14 provides means for adjusting the size of the opening 24 from fully open to fully closed. An additional opening 28 (FIG. 4) is provided with a check valve 30 which flaps open when the sidewall 16 is contracted to provide additional air expulsion from the air chamber 18. The valves and openings for regulating air flow are preferably located on the end wall 14 but could also be located, less conveniently, on the end wall 12.

An inner surface 32 of the end wall 12 is provided with a pair of foot straps 34 and 36 for holding the feet of the user. A pair of handles 37 and 38 are connected to the end wall 14 on diametrically opposite sides thereof to provide hand-holds for the user. A pair of adjustable shoulder straps 40 and 42 are likewise connected to the end wall 14. The user applies the force "AF" to the device 10 which causes expansion in the length of the sidewall 16. A reaction force "RF" is generated and delivered to the end wall 12 through the legs of the user. Of course, the forces can be reversed, and the amount of the applied force necessary to cause axial expansion is determined by the amount of a pneumatic force which resists expansion. This force is a function of the size of the opening 24, which is regulated by the user's selected position of the valve 26. The foot straps, shoulder straps, and handles facilitate application of the applied and reaction forces to the device 10.

In use, the user places his or her legs into the air chamber and adopts a leg extended position as shown in FIG. 1. This can be a vertical upright position, as illustrated, or a horizontal position if the device is suspended. In a weightless environment, any orientation can be employed. As the user moves into the knee-bent position illustrated in FIG. 2, air is expelled from the air chamber through both openings 24 and 28 and no or slight pneumatic resistance is experienced to the applied force. When the user extends the legs and thus expands the length of the air chamber 18 to thereby expand its volume, a reduced internal air pressure is generated, as compared to the surrounding ambient, and this reduced air pressure resists the axial expansion of the sidewall 16. The amount of pneumatic resistance is determined by the position of the valve 26.

FIG. 3 shows the fully collapsed form of the device when not in use. It is apparent from FIG. 3 that the device can be stored easily and in a relatively small amount of space. No radial expansion of the device occurs when contracted into the storage mode. In this position the fabric has been folded inwardly and the coiled supporting wire is stacked.

FIG. 4 is a cross-sectional view of the device 10 taken along line 4—4 of FIG. 3, and shows the inside of the top most portion of the cylindrical air chamber. The circumferential area between the outer circumferential edge of the collar 20 and the circumferential edge of the central opening provides an adjustment and sealing zone for engaging the user's torso and creating a seal therewith. The collar can be attached hermetically to the end wall 14 around the central opening using any suitable means. The material from which the collar is constructed may extend into and overlie the outer surface of the end wall 14 to enhance the hermetic seal formed between the collar 22 and the end wall 14.

The operability of the device 10 is straightforward. Exercise against the footward force produced by lower body negative pressure (LBNP) provides a simple and inexpensive technique to simulate gravity during space flight. To allow the legs themselves to generate the negative pressure against which they work, the flexible cylinder around the lower body is sealed at the waist and expands and collapses longitudinally, but not radially. As the legs push forward against the inner surface 32 to expand the cylinder, the air pressure in the cylinder decreases which in turn increases the force required to continue expanding the cylinder. The negative pressure is limited by adjustable valve 26 to allow controlled air flow into the cylinder through the opening 24. The check valve 30 remains shut during cylinder expansion, but allows air to enter the cylinder during retraction, thus simulating knee bends. It is possible to omit the check valve 30 and opening 28 thus providing two-way pneumatic resistance. Shoulder straps and handles on top of the cylinder allow the user to counteract the downward force exerted by their legs. Force produced depends on air inflow rate, cylinder radius, and length and rate of expansion.

Optionally, a vacuum gauge 44 can be provided on the end wall 14 to provide visual feedback to the user as to the amount of work that is being performed. Any conventional gauge can be employed.

Example

Seven healthy subjects (5 males, 2 females; age 23–48; height 160–183 cm; and weight 43.6–90.9 kg) performed five to six minutes of simple knee bend exercise in a device 10. Footward force (Dual Force Monitor, Electronic Quantification Inc., Plymouth Meeting, Pa.), cylinder pressure (Millar pressure transducer, Millar Instruments, Houston, Tex.), and heart rate (ECG) were continuously recorded on an eight channel strip chart recorder (Astromed 9500, Astromed Inc., Warwick, R.I.) or a computer data acquisition system (Labtech Notebook software, Laboratory Technologies, Wilmington, Mass.; DAS 20 board, Metabyte, Taunton, Mass.). Oxygen consumption was measured prior
to and during the final minute of exercise with turbine
volumetry and gas analysis. Exercise rate was guided by
a metronome set at 20 cylinder retraction/expansion
cycles per minute, and the air inlet valve was adjusted
so footward force during cylinder expansion peaked at
approximately 150% of body weight. Heart rate was
quantified during oxygen consumption measurements.

In two subjects, a maximum footward force was ob-
tained with the adjustable inlet valve 24 completely
closed, and was expressed as a percent of maximum leg
press (determined using a Nautilus device). In addition,
one subject exercised at maximum effort for one minute
with the adjustable inlet valve 24 closed, 25% open,
50% open, and 100% open: to demonstrate the effects
of air inflow resistance on exercise rate and force de-
velopment.

Supine exercise against self-generated LBNP was
comfortable and well-tolerated. Subjects tended to ex-
ceed the target peak force of 1.5 body weights: peak
force averaged 1116±87N (163±5% body weight;
Table 1). After 5 min of cyclic exercise to this level
((@19±1 cylinder retractions and expansions per minute),
mean oxygen consumption increased 6-fold from
4.7±0.3 ml O2xkg⁻¹xmin⁻¹ at rest to 30.9±1.4 ml
O2xkg⁻¹xmin⁻¹, and heart rate increased from 68±3
beats xmin⁻¹ to 143±6 beats xmin⁻¹. All subjects
could have exercised longer and at greater intensity.

Table 1 illustrates how maximal exercise rate and
force development vary with air inlet resistance in one
subject. With increasing air inlet resistance, both higher
negative pressure and peak force were generated, while
maximum rate of exercise was decreased. This subject
exceeded his maximal leg press (Nautilus) effort by 24%
when using the self-generating negative pressure exer-
ciser. Another subject (the strongest in our group)
achieved 2958N (302 kg) at maximal effort in the
leg press (determined at a Nautilus device).

Also, Exercise rate ated Generated

VOLUME

Average

15
cycles per minute, and
beats x
maximum rate of exercise was decreased. This subject existing prototype is the lack of eccentric exercise capa-
tute), mean oxygen consumption increased 6-fold from
back could
quantified during Oxygen consumption measurements. may prove beneficial to alleviate back pain experienced
force development vary with
air inlet resistance in one
tion. Other devices for the trunk and upper body could
have exercised longer and at greater intensity.
materials science experiments), simplicity, low mass,
press (determined at a Nautilus device).

One major disadvantage of the
negative pressure against which they work, and force feed-
back could be provided by a simple aneroid pressure
gauge.

Other advantages include: ease of use, low vibration
during free-floating use (to minimize impact on sensitive
materials science experiments), simplicity, low mass,
collapsability for storage, and economy of construc-
tion. Other devices for the trunk and upper body could
also employ self-generated pneumatic pressure differen-
tials to exercise against. One major disadvantage of the
existing prototype is the lack of eccentric exercise capa-
bility. Design modifications are possible, however, to
permit this type of exercise. Eccentric skeletal muscle
activation may be important for maintenance of anti-
gravity muscle strength, because existence in gravity
commonly imposes eccentric exercise on such muscles.

Nevertheless, the concept of exercising against self-
generated pneumatic pressure differentials offers a
novel and versatile new means of exercising in micro-
gravity.

An exercise method of the present invention entails
cyclically changing the internal pressure of the air
chamber by performing reciprocating exercise routines,
such as, but not limited to, knee-bends. The cycle dura-
tions and frequencies are user-determined. Certain pa-
rameters may be chosen to maximize either or both the
exercise effect and the circulatory effect.

Although the invention has been described in con-
junction with specific embodiments, it is evident that
many alternatives and variations will be apparent to
those skilled in the art in light of the foregoing descrip-
tion. Accordingly, the invention is intended to embrace
all of the alternatives and variations that fall within the
spirit and scope of the appended claims.

What is claimed is:
1. An exercise device comprising:
   a device comprising a
   first and second substantially rigid end walls; and
   a flexible, variable length sidewall extending between
   and hermetically connected to the first and second
   end walls to define an air chamber having a vari-
   able volume,
   the air chamber being adapted to enclose at least a
   portion of a user's body and having an internal air
   pressure which varies in accordance to variations
   in volume,
   the sidewall being expandable and contractible in
   length to thereby vary the internal pressure in re-

   TABLE 1

<table>
<thead>
<tr>
<th>Valve Status</th>
<th>Air Inlet Resistance</th>
<th>Cylinder Retraction rate (cycles/mm)</th>
<th>Max LBNP Generated (mmHg)</th>
<th>Max Force Generated (N)</th>
<th>% of Max (Nautilus) Leg Press</th>
</tr>
</thead>
<tbody>
<tr>
<td>100% LOW</td>
<td>43</td>
<td>23</td>
<td>943</td>
<td>96</td>
<td>47</td>
</tr>
<tr>
<td>50% open</td>
<td>35</td>
<td>35</td>
<td>1343</td>
<td>137</td>
<td>67</td>
</tr>
<tr>
<td>25% open</td>
<td>25</td>
<td>50</td>
<td>1855</td>
<td>190</td>
<td>93</td>
</tr>
<tr>
<td>closed HIGH</td>
<td>3</td>
<td>63</td>
<td>2473</td>
<td>253</td>
<td>124</td>
</tr>
</tbody>
</table>

These findings demonstrate that self-generated lower
body negative pressure exercise provides both aerobic
and anaerobic (resistance) training in supine subjects.
Exercise was performed while supine because recum-
bency simulates the musculoskeletal and cardiovascular
unloading found in microgravity. Therefore, these re-
results document the potential for the invention to pro-
vide both aerobic and resistance exercise in micro-
gravity.

The exercise device 10 possesses many features
which make it attractive for use during space flight.
First, it is safe: workload is controlled and limited en-
tirely by the user, no potentially dangerous inertial
forces are generated, and the maximum attainable
LBNP levels (about 70 mmHg) are transient and user-
dependent. Second, the device 10 exercises primarily
the large anti-gravity muscle groups in the legs and
back in a manner similar to a standing leg press. These
muscles are very susceptible to microgravity-induced
atrophy, and therefore in need of exercise during space
flight. Also, spinal loading from this type of exercise
may prove beneficial to alleviate back pain experienced
by astronauts. Third, exercise with this device hypo-
thetically elicits intermittent increases in lower body
vascular transmural pressures, and may effectively sim-
ulate the circulatory conditions of upright exercise on
Earth by redistributing blood and body fluids from
upper to lower body. Fourth, the self-generating LBNP
exerciser provides a wide range of exercise rate and
workload by simply adjusting the air inlet resistance.

Fifth, the body is ventilated by the cycling of air in and
out of the cylinder. (Lack of convection in micro-
gravity hypothetically reduces air flow over the skin
during exercise.) Sixth, the device requires no external
power source: the user's movements generate the nega-
tive pressure against which they work, and force feed-
back could be provided by a simple aneroid pressure
gauge.
response to a force applied to one of the first and
second end walls by the user,
the applied force generating a reaction force deliv-
ered to the other of the first and second end walls,
and the applied force being resisted by a pneumatic
force generated by a difference between the internal
air pressure of the air chamber and ambient air
pressure outside the air chamber.

2. An exercise device according to claim 1, further
comprising means for regulating air flow into the cylin-
der during expansion to thereby adjust the pneumatic
force.

3. An exercise device according to claim 2, wherein
the regulating means comprises a first opening formed
in the first end wall and a first valve member pivotally
connected to the end wall to permit movement of the
valve member over the opening.

4. An exercise device according to claim 1, further
comprising check valve means for exhausting air from
the air chamber during one of expansion and contrac-
tion of the sidewall.

5. An exercise device according to claim 1, further
comprising first retaining means for holding the portion
of the user's body contained in the air chamber to one of
the first and second end walls, and second retaining
means for holding a portion of the user's body disposed
outside the air chamber to the other of the first and
second end walls.

6. An exercise device according to claim 1, wherein
the first retaining means comprises foot straps disposed
on an inner surface of the second end wall.

7. An exercise device according to claim 6, wherein
the second retaining means comprises adjustable shoul-
der straps connected to an outer surface of the first end
wall.

8. An exercise device according to claim 7, wherein
the second retaining means further comprises a pair of
handles disposed on the first end wall.

9. An exercise device according to claim 1, further
comprising access means, disposed in the first end wall,
for sealingly permitting ingress and egress of the por-
tion of the user into the air chamber.

10. An exercise device according to claim 9, wherein
the access means comprises a central opening forming
in the first end wall with an elastic collar disposed
around the central opening for sealingly engaging a
portion of a user's body.

11. An exercise device according to claim 1, wherein
the sidewall is made of a rubberized fabric connected to
a coiled wire support.* * * * *