VIBRATIONARY EXERCISE EQUIPMENT

Inventors: David Paul Sumners, Middlesbrough (GB); Roger Leslie Brown, London (GB)

Correspondence Address:
BARKUME & ASSOCIATES, P.C.
20 GATEWAY LANE
MANORVILLE, NY 11949 (US)

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ABSTRACT
A muscle training apparatus arranged for cyclic concentric and eccentric loading phases including load imposition means arranged for a user to exercise against load variation means arranged for varying the load as between concentric and eccentric loading phases, a vibrator operational to apply vibration between the user and the load, a controller operational to control the vibrator and to vary the extent of vibration as between concentric and eccentric phases.
Fig 20

Solenoid Valve

1N4002

24v DC

BCX38C

V vs applied control signal

Pull Down Resistor 100k

Fig 21

Resistance to Airflow vs Time (valve action)

24v

Applied Solenoid Valve Voltage vs Time

0v

2ms 2ms
TYPICAL SWIPE CARD ENTRY MICROPROCESSOR BASED CONTROL SYSTEM FOR FLUID FLOW CONTROL OF VIBRATION AND OTHER PERFORMANCE CHARACTERISTICS

Fig 25
VIBRATIONARY EXERCISE EQUIPMENT

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This is a continuation-in-part of U.S. application Ser. No. 11/733,271 filed Apr. 10, 2007, which is a continuation-in-part of U.S. application Ser. No. 10/507,150 filed Mar. 12, 2003, which are both incorporated in their entirety.

BACKGROUND OF THE INVENTION

[0002] The present invention relates to exercise equipment and is particularly concerned with such sports, exercise, well-being and medical training and therapeutic equipment having the facility to combine vibration with mechanical loading on the muscles and bone structure of users.

[0003] The use of vibration in the context of strength training (where the expression strength training is being used herein to describe any exercise facility in which a load is applied to muscles of a user) induces a non-voluntary muscular contraction called the “tonic vibration reflex”. Weight training with additional vibration has been shown to augment strength and power output and above that achieved with strength training alone. This effect is achieved through the recruitment of additional muscle fibres above the normal recruitment level. Vibration has also become a common tool used in the retardation of muscle and bone atrophy on earth and in space.

DESCRIPTION OF RELATED ART

[0004] Currently commercially available weight training devices rely either on un-modulated loads or full body vibration. These devices apply no vibrational loading at all, or fail to apply directly specific frequencies to targeted muscle groups. Some such full-body vibration systems can also quickly lead to discomfort and other negative physical side effects.

[0005] A publication in Journal of Sport Sciences 1999, 17, 177-182 discloses the effect of vibrationary stimulation on bilateral biceps curl exercises. According to this publication the superimposed vibration during the exercise was transmitted to the muscles by a specially designed vibratory stimulation device. This consisted of an electric motor with a speed reduction facility and eccentric wheel. The load was held by a cable passed through the eccentric wheel via pulleys. The eccentric rotation elicited peak-to-peak oscillations of 3 mm with a frequency of 44 Hz. After vibration damping caused by cable transmission, the acceleration on the handle was about 30 m/s^2 (RMS). Vibration from the two-arms handle was transmitted through the contacting muscles involved in the pulling action.

[0006] A particular disadvantage associated with the use of vibration which is directly electrically generated is the difficulty of applying the vibration directly to the user throughout the various configurations of the equipment. There is a mismatch between the mechanical and electrical operation which impedes obtaining maximum benefit from the application of vibration. Moreover non-smooth contraction of muscle has been observed in weight training equipment utilizing electric motor driven vibration devices.

[0007] We have now devised an improved apparatus for enabling vibration to be transmitted to a person exercising.

SUMMARY OF THE PRESENT INVENTION

[0008] According to the present invention an exercise apparatus comprises a fluid pump means operated by movement of the user and control means arranged for intermittently varying fluid flow in the pump means thereby to impart vibration to the user.

[0009] A vibration frequency to provide benefit may be from 1 Hz to 100 Hz, preferably from 10 Hz to 35 Hz. Where this is obtained in a rotary or oscillating, eg solenoid, valve, closure of the valve every 0.1 to 0.3 seconds for a period which may be 50%, but could be more or less of the time, ie 0.05 to 0.015 seconds the user will experience for a very short period an increase in resistance superimposed on that of the real or simulated weight.

[0010] According to a feature of the invention the fluid pump means may also incorporate static resistance means whereby the fluid pump imposes the load as well as the vibration on the user.

[0011] Advantageously the exercise apparatus may comprise a piston cylinder arrangement whereby tension and compression are effected as between the piston, via a connecting rod, and the cylinder. Then a fluid circuit connected to the interior of the cylinder on both sides of the piston can be arranged to carry the vibration facility.

[0012] By this means the exercise apparatus can readily be arranged to load the user in both directions, push and pull, compression and tension. It can be made relatively compact so as to be portable for use in one hand or between a user’s two hands for arm strengthening and “chest expanding”, although arrangements for such operation between other parts of the anatomy are also readily possible.

[0013] The static load can be realized in a restrictor or pressure relief valve means, which are advantageously adjustable to provide different loads and equipped with an indicator of the load being applied. By use of a non-return valve for example the load can be arranged to differ as between the two directions, while a control cock arranged to block or open the non-return valve can be employed to convert the apparatus between uni-directional and bi-directional strength training.

[0014] A perhaps non-adjustable part (or whole) of the resistance to motion can be obtained in a bleed through the piston, with differential load being obtained via a non-return valve and or a pressure relief valve also if necessary located in the piston. The vibration can readily be arranged to differ as between push and pull as well.

[0015] The fluid may be a gas such as air or nitrogen or a liquid such as an hydraulic liquid. If, in the case of a liquid, damping of the vibration is desired and is not achievable by padding with, for example, foam, or by employing a viscous liquid as the medium, a gas cushion or valve device may be incorporated to achieve this.

[0016] Where gas is employed, it has been found that compressing the gas to a pressure of 4.5 bar creates an effective transmission of reactive force without excessive damping. Pressures from 2 bar up to 4.5 bar provide progressively less damping action and thus the absolute pressure to which the system is primed can be used to effect the maximum reactive force generated and the damping characteristic of the vibration effect felt by the user.

[0017] According to another feature of the invention the fluid pump means may be interposed between an operating
bar arranged to be pushed and/or pulled by a user, and a base, which may be a static part of the apparatus. It is preferable for the fluid pump means to be linked to the operating bar substantially directly to avoid losses and unwanted damping of the vibration. Such a fluid pump vibration means can readily be constructed as a retrofit to an existing weight training equipment.

[0018] The vibration may be generated in the fluid pump means by a motorised valve incorporated therein. The valve may be a solenoid valve, diaphragm valve or a rotary valve inter alia.

[0019] In the case of a solenoid valve of the type constructed to operate with fluid flow in only one direction, a bridge configuration may be employed. Often also solenoid valves have limited flow rate capacity for a given reasonable power or a high flow resistance. The employment of an array of such valves in parallel to overcome this can confer a particularly significant advantage, discussed below, that of applying random vibration.

[0020] It is often desirable to employ vibration only when lifting a weight or in a single direction of motion of the equipment and this apparatus in accordance with the invention can readily be arranged for this to occur. Where solenoid valves are used the preferred unpowered valve status is OPEN such that until powered the solenoid valve will allow free passage of fluid.

[0021] A preferred solenoid valve is the Festo™ low latency solenoid valve type M1E2-S with a 2 ms (two microsecond) latency and employing internal electronics to permit fast switching.

[0022] If one or more rotary valves are used instead of solenoid valves, these can be readily be driven by one or more electric motors, which may be AC or DC and brush, induction or homopolar motors. Ideally the motor operation is so controlled that speed or speeds can be set selected and controlled to an accuracy of 10%, preferably 1%.

[0023] A yet alternative motor is a stepper motor employing electronic commutation and multiple poles such as 2 pole, 4 pole, or 5 pole fixed coil arrangements and multiple poles on the rotor. This enables half-or micro stepping, allowing for example 200 micro steps per revolution of 1.8° per step. The rate of revolution can be set by a hardware or software clock signal applied to selected coils by a dedicated integrated circuit or discrete electronic hardware control circuits. This makes a stepper motor particularly suitable in contexts where a variety of valve speeds is desired. When operating a stepper motor the rate of coil pair energization and thus rotary speed is controlled by the rate of application of electronic signals. As the rate of energization may be varied to produce a range of speeds, and the specific poles selected with respect to their disposition around the rotor is also selectable, there is a measure of control available that allows the angular speed to vary within less than one revolution per second. Thus random or pseudo random variability in valve opening and closing times may be effected through control of the stepper motor coil energization order and speed.

[0024] As has been indicated above, it is particularly advantageous for the applied vibration to be arranged for random or even pseudo random amplitude and frequency. The effect on muscle development of such an arrangement is particularly marked. By pseudo random is meant a cycle of variation long enough to be substantially unpredictable to the user. Pseudo random variation can be obtained using two motorised valves, solenoid or rotary inter alia, in parallel in the fluid flow circuit, and arranged to operate at different speeds. Thus the combined resistance created varies over time as valve open and closed times move into and out of synchronicity.

[0025] The rotary motor driven valve itself may be an offset valve of the type disclosed in PCT Patent Application PCT/ GB2006/050314 and UK Patent Application 0520195.9. This valve comprises (i) a housing containing a fluid flow path with a central axis, (ii) a plug having a seating face co-operating with said housing in the closed position to block the fluid path, and (iii) a support shaft arranged to carry said plug means and being rotatable on an axis which is normal to and spaced from the axis of said valve seat and located outside of the fluid path so that rotation of the said shaft moves said plug means relative to said housing. The shape of the vibration pulse obtained with such a rotary valve will depend upon the nature of the valve core offset and the shape and size of the core recess.

[0026] Advantages of a valve of this kind are that (1) when fully open there is no occlusion of the opening, and (2) the valve opens and closes only once per revolution. This latter reduces or obviates the gearing which might otherwise be required when employing a motor the normal speed of which would otherwise impose too high a vibration frequency.

[0027] Whatever the type of valve employed, when a liquid rather than a gas is employed as the fluid, it may be advantageous to permit a small throughput of fluid even when the valve is ostensibly closed. With a rotary valve this may be achieved with an appropriate passage through the obturator or a groove therearound.

[0028] Many weight training equipments carry some form of dampening structure to provide user comfort, particularly those equipments which bear upon the user’s shins for example. Normally this might comprise a plastics foam, particularly one which under the influence of body warmth and pressure distorts to mould itself to the profile of that part of the body applying the force. It would be expected that the use of such foams would largely attenuate the transmission of vibrations. However Conforfoam™ type “CF-47 green” produced by F.A.R. Speciality Composites has been found to have good vibration transmission characteristics without compromising comfort.

[0029] It may in fact be advantageous, not least from the point of view of simplicity of retrofit or upgrade assembly, when employing a foam having good vibration transmission characteristics, to locate a vibration generating device within the operating arm of an exercise machine, including within the foam itself.

[0030] There is some evidence to suggest that random direction vibration may be counter-productive to the efficacy of vibrated training and that applying the vibration in the direction of muscle stress yields the better results with reduced fatigue and reduced potential nausea. A linear vibration mechanism can be achieved using a fluid circuit as herein described though retrofit in the arm or foam can be simpler if an electric motor is used to generate the vibration. The motor may be arranged to drive a crank coupled through a connecting rod to a crosshead to which is attached a relatively large mass, the crosshead being constrained by guide bars to shuttle linearly. Other mechanisms for translating rotary motion to linear may of course be used.

[0031] A typical application of this embodiment of the invention is in a leg-extension training apparatus. An arm pivoted at a point coinciding with the user’s knee joints is, in this application, associated with training weights and carries
a padded bar arranged for bearing low on the legs of the user, a linear vibration device being located within or inside the padding and arranged so that in operation the vibration is in the same direction as the force applied to lift the weight.

[0032] By employing motorised flow rate control valves in conjunction with microprocessor based controllers the equipment may be arranged to read smart cards, swipe cards or other data entry means including keypads, touch screens, voice control or wirelessly linked data transfer using RFID or other technologies. In this way the apparatus may be adjusted to suit an individual user’s training and physiological characteristics and specified programme, according to real time software algorithms, look up tables or other rules or pre-programmed sequences.

[0033] It may be desired to incorporate readout devices for indicating the weight and/or vibration applied and the amplitude of apparatus expansion or compression. To those skilled in the art there are many ways of detecting the position and direction of motion of parts of strength training apparatus in accordance with the invention, including microswitches, electrically resistive means, capacitive and inductive sensors, opto-electronic devices, Hall Effect magnetic devices, reed switches or other similar components which may be read sequentially or incrementally by interaction with moving parts of the equipment. Electronic means including simple circuit arrangements creating sequential state machines or more sophisticated arrangements including stored memory devices such as RAM or other temporary storage means may be used, preferably with a microprocessor to control the recording or processing of information about the order of events such that this information may be used to switch the vibration inducing solenoid OPEN for a particular part of the cycle of operation or control other features of the performance, such as mark-space ratio or if the weight simulating valves are motorised the balance between vibrated and background resistance generated by the apparatus or other parameter thereof. In this case the electronic means of control can be arranged to apply selectively the vibration resistance to the user and control the level and timing of all resistive elements of the load application.

DESCRIPTION OF THE DRAWING

[0034] Various embodiments of the invention will now be described by way of example with reference to the accompanying drawings, of which:

[0035] FIG. 1 is a side view of an embodiment of the invention attached to an exercise machine;

[0036] FIG. 2 is a front view of FIG. 1;

[0037] FIG. 3 is one disc used in a different embodiment of the invention;

[0038] FIG. 4 is a second disc;

[0039] FIG. 5 shows the discs of FIGS. 2 and 3 in position;

[0040] FIG. 6 shows a breathing apparatus using the invention;

[0041] FIG. 7 shows a hydraulic damping system applied to a weight machine;

[0042] FIG. 8 is a schematic view of a simple “stand alone” two-way vibrationary muscle training device;

[0043] FIG. 9 is a schematic view of a simple “stand alone” one-way vibrationary muscle training device;

[0044] FIG. 10 is a schematic view of a closed circuit vibration device for fitment in a weight training apparatus and pneumatic solenoid valve operated;

[0045] FIG. 11 is a schematic view of a closed circuit vibration device for fitment in a weight training apparatus and having hydraulic and by-pass valves;

[0046] FIG. 12 is a schematic view of a closed circuit vibration device operated by a motorised rotary valve;

[0047] FIG. 13 depicts a cutaway valve core used in an offset rotary valve arranged for one closure per revolution;

[0048] FIG. 14 is a schematic section of a rotary valve having a core as shown in FIG. 6;

[0049] FIG. 15 is a schematic diagram of the fitment of a closed circuit vibration device to a weight training apparatus;

[0050] FIG. 16 is a schematic view of a closed circuit vibration device having two rotary motorised valves in parallel, for inducing pseudo-random vibration;

[0051] FIG. 17 shows a parallel valve Magnitude vs Frequency spectrum;

[0052] FIG. 18 shows a parallel valve configuration wave-form;

[0053] FIG. 19 shows a full bridge fluid circuit for permitting uni-directional flow of fluid regardless of piston direction;

[0054] FIG. 20 is a power amplifier circuit for driving a 24v solenoid valve from a 5v control signal;

[0055] FIG. 21 is a graph of a simple control signal employed in switching a solenoid valve and the latency of valve operation;

[0056] FIG. 22 is a schematic cross section of a padded vibration arm with a rotary eccentric bob-weight;

[0057] FIG. 23 is a schematic view of a linear vibration device showing a crank, a connecting rod, a crosshead and guide bars;

[0058] FIG. 24 is a diagram of a linear vibration device added to a leg extension machine;

[0059] FIG. 25 is a block diagram illustrating a swipe card information entry system;

[0060] FIG. 26 is a schematic view of an embodiment of the invention with piston located valves and mounted in weight training apparatus;

[0061] FIG. 27 is a schematic view of a stand alone embodiment of the invention with piston located valves;

[0062] FIG. 28 is a schematic view of a variable vibration embodiment;

[0063] FIG. 29 is a schematic diagram of a one way vibration embodiment;

[0064] FIG. 30 is a schematic diagram of an incrementally loaded embodiment;

[0065] FIG. 31 is a schematic diagram of a variably incrementally loaded embodiment;

[0066] FIG. 32 is a diagram with a further development, taking as its starting point the system illustrated in FIG. 31;

[0067] FIG. 33 is a diagram of a system in which the actual weights is replaced by a compressible system, particularly a gas system; and

[0068] FIG. 34 is also a diagram of a system in which the actual weights is replaced by a compressible system, particularly a gas system.

DETAILED DESCRIPTION OF SPECIFIC EMBODIMENTS

[0069] Referring to FIGS. 1 and 2 a belt (1) is connected at one end to the weights lifted by the user and the other end is attached to the band grips moved by the user. A roller (2) has rubber pads (3) positioned around its circumference. Roller (4) is positioned so that the band (1) is gripped between rollers
(2) and (4). In use, as the user pulls on the weights, the band moves and causes the rollers (2) and (4) to rotate. As the band passes over the pads (3) a vibration is given to the band which vibration is passed onto the user via the hand grips. This vibration acts on the muscles being exercised and the frequency of vibration can be controlled by the number of pads (3).

[0070] Referring to FIGS. 3, 4 and 5 a first disc (5) has two holes (6) in it and a second disc (7) has holes (8) of varying size in it. The two discs are located on a common axis and the disc (5) is connected to a motor. As the disc (5) is rotated by the motor, the holes (8) are periodically coincident with the holes (6).

[0071] Referring to FIG. 6, the discs are mounted in a chamber (11) with an air conduit (10) passing through it with one end connected to mouthpiece (9). The air conduit is positioned so that it connects to a hole (8) and so, as one of the holes (6) is coincident with the hole (8) a continuous air passage is formed and, as the hole (6) moves out of coincidence, there is an interruption to the air supply and this periodic interruption causes a vibration effect in the breathing muscles of the user. The rate of flow of the air to the user can be controlled by the size of the hole (8) used and the frequency of vibration controlled by the speed of rotation of the disc (5).

[0072] Referring to FIG. 7 a weight lifting machine comprises a fixed framework (21), a sliding member (22) and attached adjustable weight (23) which may slide up and down guide rails (24) when a person pulls on cable (25) which is guided over pulley (26), being connected to the sliding member (22) and weight (23). The sliding member (22) is attached to a piston (27) which is located in a cylinder (28).

[0073] When cable (25) is pulled, the sliding member (22) with attached weight (23) is moved upwards against gravity providing a working load to the user’s muscles, the piston (27) displacing air in cylinder (28) out through port (29). The air displacement is checked by a control valve (30) which is driven on and off at the desired frequency by a controller (32), causing the air flow to be intermittently interrupted before release to atmosphere via port (31). The switched air-flow checking action of control valve (30) provides a time variant damping, low over and above that provided by the lifted weight (33), translating vibration into the operator’s muscles employed in the lifting action.

[0074] The embodiments depicted in FIGS. 8 and 9 are stand alone vibrationary muscle training devices which may be used for example between the two hands or, with suitable means for attachment to the limbs, between any two limbs or even between a limb and another part of the body, or between one part and another of a jointed limb.

[0075] Thus, FIGS. 8 and 9 show a piston 100, connecting rod 101 and cylinder 102 arrangement wherein the left hand end of the cylinder 102 is arranged for association with one limb of a user, for example, and the connecting rod 101 is arranged for association with another of the user’s limbs. A bypass conduit 103 from the cylinder at both sides of the piston has, in the case of the FIG. 8 embodiment, two parallel sections, the first incorporating a controllable valve 104 and the second a controllable valve 105 and a solenoid valve 106. The solenoid valve 106 is arranged for being pulsed open and closed at one or more desired frequencies while the valve 105 is arranged to control the amount of fluid passing through the solenoid valve 106. The section with the valve 104 has the function of applying the main resistive force in the apparatus and the valve 104 is adjustable to vary this force. By adjusting both valves 104, 105 a ratio of main resistance to pulsed resistance can be varied.

[0076] The FIG. 9 embodiment has a uni-directional, or non-return valve 107, in parallel with the other two parallel sections. This permits free movement of the piston 100 in one direction for situations where strength training is only required in the one direction.

[0077] FIGS. 10 to 14 relate particularly, but not necessarily exclusively, to a vibration device adapted for fitment to a strength training apparatus, in particular a weight training apparatus, perhaps by retrofit.

[0078] In FIGS. 10, 11 and 12 there is a piston 200, connecting rod 201, and cylinder 202 arrangement. A bypass conduit 203 from the cylinder 202 at both sides of the piston 200 has, in the case of the FIG. 3 embodiment, a solenoid valve 204. The function of the solenoid valve 204 is, by rapid cyclic opening and closing, to impart vibration to the fluid in the cylinder. The solenoid valve 204 is accordingly arranged for being pulsed open and closed at one or more desired frequencies.

[0079] The FIG. 11 embodiment has, as well as the solenoid valve 204 for imparting vibration, a variable opening valve 205 for effecting control over the resistance experienced.

[0080] The embodiment illustrated in FIG. 10 is particularly suited for use with a gas such as air or nitrogen, where no additional damping might be required. The gas is pressurized to 4.5 bar. This is sufficient to prevent excessive damping.

[0081] The embodiment illustrated in FIG. 11 is particularly suited for use with an hydraulic liquid. As damping is apt to be required when a liquid is used, the variable opening valve 205 caters for this.

[0082] The embodiment illustrated in FIG. 12 has a rotary valve 210 in place of the solenoid valve 204. An electric motor and any necessary gearbox 211 drives a valve core with a cut-away permitting selective passage of fluid depending on the relative angle of the core with respect to the fluid flow ports. The rotational speed of the valve core sets the derived frequency of the vibration. The electric motor is of the variable speed variety.

[0083] FIGS. 13 and 14 illustrate a particular form of a valve 210 for which the rotational speed equates to the vibration frequency. The valve has a cylindrical core 212 which has a recess 212a and is offset to a bore 213 of the valve so that when the recess 212a is presented to the fluid flow bore 213, fluid passes freely through the bore 213. This valve is of the type disclosed in PCT Patent Application PCT/GB2006/050314 and UK Patent Application 0520195.9.

[0084] In a variation to the valve 210 particularly useful where the fluid is a liquid, the core 212 shown in FIG. 6 has a circumferential groove, illustrated by dotted lines 214. This has the function of dampening the vibration and rendering it less harsh to the user.

[0085] The devices shown in FIGS. 10, 11 and 12 are adapted for fitment between the static frame 300 and the user operated part 301 of a typical strength training apparatus as shown in FIG. 8. The actual device shown is a weight training device where the user operated lever arm 301 is pivotally attached to the frame 300. A wire 302 attached at one end to the arm 301 distal from the pivot point passes over a frame mounted pulley 303 and is attached at its other end to a variable weight block 304.
FIG. 16 depicts a pseudo random vibration apparatus. A fluid conduit 220 connected to the cylinder 202 at both ends thereof has two parallel circuit arms 221, 222 in each of which is a rotary valve 223, 224 driven by a variable motor 225, 226. The speeds of the motors 225, 226 are controlled by a controller 227 adopted to control the base speeds of the two motors in accordance with a desired vibration variation.

FIG. 17 is a graph of a typical pseudo random vibration variation achieved with the apparatus described with reference to FIG. 16 when the two valves 223, 224 are run at different rotational speeds. The graph represents the Magnitude vs Frequency spectrum experienced when these two rotational speeds are quite close and as shown is typical of the situation which arises whenever the ratio of frequencies is low.

FIG. 18 translates the graph of FIG. 10 into a waveform of flow amplitudes vs time.

The fluid circuitry illustrated in FIG. 19 has a plurality of solenoid valves 250 in parallel in a one-way valve 251 bridge circuit associated with a fluid conduit 203. Primarily this circuitry ensures that vibration is only applied in one direction, the direction of pressure, and is absent during the relaxation movement. The employment of a plurality of solenoid valves 250 in this way enables amplitude and randomness of vibration to be controlled. The circuit includes a fluid charging/pressurising valve 252.

FIG. 20 shows a typical solenoid valve drive circuit permitting a TTL 0 to 5V DC signal to drive a 24V DC solenoid valve with catch or flywheel diode to prevent a back emf from the inductive solenoid coil from damaging the transistor.

Referring to FIG. 21, a solenoid valve takes time to operate, due to the mass of the valve plug and the inductive nature of the drive coil there is a delay, often called latency, which limits the maximum speed at which the valve can operate. In many fast solenoid valves the latency is in the range 2 ms (two microseconds) to 4 ms. In such cases to turn ON and OFF and complete one cycle the fastest theoretical on-off cycle or period will be in the range 4 ms to 8 ms, giving a maximum frequency of 50 Hz to 125 Hz respectively. In practice there are other delays in reversing the field in a solenoid coil, and damping constraints, that limit the maximum frequency of operation to 50 Hz. Under load this may drop to 25 Hz. If higher speeds are required without resort to specialised solenoid valves, then the motorised rotary valves also discussed above may be employed.

FIG. 22 shows a cross section of a bar or lever 400 in a strength training device subject to vibration in accordance with the invention. The bar or lever 400 is surrounded by a closed cell foam 401 supporting an outer tube 402 which is in turn covered by a foam pad 403. The foam pad 403 is formed of Conforfoam™ type CF-47 green. This foam, whilst conforming to the local shape of, say, the user’s lower shins, is particularly capable of transmitting vibration without significantly damping it.

In the particular case shown in FIG. 22, a vibration device is attached to the interior of the outer tube 402 in a recess in the foam 401. The vibration device comprises a bob-weight 410 associated with an electric motor 411.

The linearity of this vibration, constrained for alignment with the direction of the user’s muscle strengthening procedure, is obtained with a device as depicted in FIG. 22. An electric motor driven crank 420 in turn drives a connecting rod 421 linked to a crosshead 422 constrained for reciprocal linear motion by guide bars 423.

The tube 402 may be formed of a metal such as an aluminium alloy and the foam 401 may be a sponge rubber or a “sorbo rubber”.

In a modification of the device illustrated in FIG. 22 the configuration of the vibration device is adjustable so that the vibration direction can be regulated.

Application of the devices illustrated with reference to FIGS. 22 and 23 to a leg muscle strengthening apparatus is illustrated in FIG. 24. This shows a lever 430 associated with an adjustable weight block 431 and arranged to pivot around a point 432 adjacent a user’s knees. The lever 430 carries an arm disposed for contact with a lower region of a user’s shins, the arm being as described with reference to FIG. 22. The vibration device illustrated in FIGS. 22, 23 is arranged to vibrate linearly along the arrowed line 433 in FIG. 24. It is also adjustable so that the vibration direction can be regulated. FIG. 25 is a block diagram illustrating a microprocessor based control system for the entry of a user’s programme and accordingly the control of loading and vibration. Alternative or complementary inputs, in the form of a swipe card entry unit and a keypad entry unit enable the user to input his individual programme and to vary it if desired. A USB entry/ save to external device unit provides to the user both an indication of his progress with the apparatus and any required modification to the swipe card or user programme store.

The microprocessor is configured to control the valves and read any sensors on the apparatus, which responds using stored programme control configured or modified by keyboard, USB etc inputs or swipe card. The swipe card can store any personal custom configuration for the adjustment and regulation of frequency, load and other parameters such as sensor sensitivity, number of repeat cycles to be done at each setting etc and store any results generated on the card as required if swiped before quitting, perhaps even setting an adjusted programme for a future visit.

The ROM memory contains the operating system and standard settings and process control information.

The RAM memory is used for storing operational parameters and other data associated with the micro operation during use as well as usually temporarily storing configuration and personal data uploaded from the swipe card during use including possibly billing information for equipment use sent out either via the networking port/wireless port etc to a central gym management data system.

The Flash/EZPROM memory is used to store patches uploaded from the repro port to correct or upgrade the operating system/process control code in the event of errors or other need for modifications to the electronic control systems.

The network port may be used to transfer real-time data to a central PC or other data store for tracking, billing or performance mapping of either the machine or individual users. This may be interactive such that changes to the behaviour of the machine may be directly effected or a new training configuration be downloaded to the swipe card for the next usage session by that user.

It may also be arranged to provide random variation of the vibration.

It will be appreciated that any of the devices described with reference to the accompanying FIGS. 8 to 25 may be employed in both stand alone strength training devices and in equipment, such as gymnasium or physi-
therapy weight training equipment in which the weight or other load is applied separately to the vibration facility. [0105] In that respect, FIGS. 26 and 27 show similar embodiments of the invention, one mounted in a weight training apparatus (FIG. 26) and the other (FIG. 27) as a stand alone device.

[0106] Thus the device illustrated in FIG. 26 is a weight training apparatus in which a frame 500 carries an adjustable weight block 501 and a pulley 502 over which runs a metal rope 503 attached at one end to the weight block 501 and at the other to a lever device (not shown) for operation by a user. Between the weight block 501 and the frame 500 is a vibration generator in the form of a piston 504, hollow connecting rod 505, cylinder 506 and connecting rod base 507.

[0107] A pair of channels 508 communicate between both faces of the piston 504 and there is a pair of solenoid valves 509 arranged for controlling the flow in the channels 508. Electric leads 510 pass between the valves 509 and a junction 511 in the base 507. Electricity supply is derived at 512 and controlled at the control panel 513, which also provides a display of operating conditions.

[0108] The fluid in the cylinder being a cock 514 is provided by which the gas can be pressurized to 4.5 bar.

[0109] When the weights 501 are lifted and the solenoid valves 509 powered flow from one face of the piston 504 to the other is interrupted continuously and a vibration imparted to the rope 503. There being two solenoid valves 509, the piston cylinder arrangement can be switched to either simple vibration mode or pseudo random mode.

[0110] The device illustrated in FIG. 27 comprises a closed cylinder 600 having a base 600a and in which slides a piston 601. The piston is mounted rigidly on a hollow connecting rod 602 which emerges from the cylinder 600 and to which is rigidly mounted a handle 603. A rod 604 is rigidly attached to the cylinder base 600a enter and run in the hollow of the connecting rod 602. The rod 604 has a helix formed thereon. A disc 605 is held to the piston 601 so as to be free to rotate with respect thereto. The disc 605 is mounted on the rod 604 in such a manner that longitudinal movement of the piston 601 with respect to the rod 604 will cause the disc 605 to rotate. The disc 605 is of smaller diameter than the piston 601. Channels 600 provided with non-return valves 606a pass through the piston 601 outward of the disc 605 to permit a continuous but restricted fluid flow therethrough in a compression direction and free flow therethrough in a tensile direction. Channels 607 through the piston 601 inboard of the circumference of the disc 605 are arranged to align intermittently with channels 608 through the disc 605. A plug 609 in the handle 603 enables charging the cylinder 600 with fluid and pressurizing same.

[0111] The rod 604 and the disc 605 are made or coated with a low friction material such as PTFE or nylon. Typically the angle of the helix to the axis of the rod 604 is 8°.

[0112] In operation of the device illustrated in FIG. 27, when fully charged with fluid, a compressive force between the handle 603 and the base 600a of the cylinder 600 moves the piston/disc 601/605 assembly toward the base 600a, the resistive load depending upon the size of the channels 606. This movement causes rotation of the disc 605 with respect to the piston 601, intermittently aligning the channels 607 and 608 and thereby creating an intermittent resistance to the compressive movement. When returning the apparatus to fully extended the non-return valves 606a open to permit relatively unrestricted fluid flow through the channels 606.

[0113] If adjustability were to be required of a device such as that illustrated in FIG. 27, this may the most simply be obtained via an adjustable valve in a channel connecting both ends of the cylinder 600 and exterior thereto, unless remote controlled valves were installed in the piston 601 somewhat as illustrated in FIG. 26.

[0114] U.S. Pat. No. 4,930,770 (Baker) discusses various categories of exercise devices used for muscular development.

[0115] Isokinetic devices regulate or control the rate of muscular contraction regardless of the force applied to the device by a user's muscular contraction. For example, in an isokinetic device where a weight is attached to a bar and where the user initiates actions with the bar, the isokinetic device only regulates the speed of the movement of the bar. U.S. Pat. No. 4,483,532 teaches the use of a centrifugal brake to increase movement resistance as the velocity of the exercise bar is increased above some preset value. U.S. Pat. No. 4,363,480 teaches the use of a centrifugally regulated frictional resistance device to control the speed of a treadmill regardless of the amount of force exerted by the user.

[0116] Another class of devices provide for positive only non-eccentrically loaded use. These devices provide for the regulation of the resistance force against the user, only when the bar is moving, but do not control the bar speed during the exercise, such as when a muscle contracts during a positive exercise. For example, U.S. Pat. No. 4,354,676 teaches the use of a computer controlled valve to regulate the internal pressure of a hydraulic cylinder connected to the exercise bar. U.S. Pat. No. 4,609,190 teaches the use of a double acting hydraulic cylinder with an assorted control valve for each cylinder to resist the exercise bar movement by providing a different resisting force for resisting movement. However, most of these hydraulic devices provide for positive exercise only.

[0117] Whereas many of these positive only exercise devices utilize a hydraulic cylinder to vary the resistance force, some machines use an electrically controlled friction brake which is typically coupled between the exercise bar and the user. The resisting force is varied by the amount of friction applied to a rotating member on the exercise bar. U.S. Pat. No. 4,261,562 teaches the use of a DC generator as a variable force resistance device in which the electrical loading coupled to the generator is varied. U.S. Pat. No. 4,063,726 also utilizes a hydraulic cylinder and having an electronically controlled valve to vary the resistance force.

[0118] A third category of exercise devices deals with positive and negative stroke operating devices. This category contains a wide variety of mechanical, electronic, and electromechanical devices to provide exercise in both positive and negative directions. For example, U.S. Pat. No. 3,858,873 provides for a use of a spiral cam coupled between the exercise bar and a stack of metal weights to provide an increasing force during a positive exercise stroke. U.S. Pat. No. 3,848,467 uses a speed controlled motor in the negative stroke and a friction brake in the positive stroke of an exercise. U.S. Pat. No. 4,569,518 utilizes a variable torque transmitting clutch for both positive and negative stroke control. U.S. Pat. No. 4,235,437 teaches the use of a hydraulic pump and electrically controlled valves to vary the force or the speed of positive and negative strokes.

[0119] Although various exercise devices are described above in relation to a number of example exercise categories, most of these devices stress a particular type of exercise for
achieving maximum muscle development. It is generally known that maximum isolation of a given muscle by a particular exercise device produces the greatest amount of strength increase during exercise. Secondly, because the strength of the muscle varies, depending on its degree of contraction, and because the amount of force that the muscle can apply varies by the bone-joint angle, the resisting force must vary as a function of the contraction of the muscle to attain maximal strength gained during the exercise.

[0120] The various exercise devices described above, although based on various exercise theories, provide for muscular development by providing a resistive force to a contracting muscle. Muscle contraction can be generally classified as being concentric, isometric, or eccentric. Concentric contraction refers to a situation of the muscle when it shortens its length. A simple example of concentric contraction is when a weight is lifted from a rest position. Because the weight is accelerated from its initial position, positive work is achieved as the contracting muscle expends energy in lifting the weight. This is referred to as positive exercise.

[0121] Isometric contraction occurs when two forces are at equilibrium so that movement cannot occur. Although work is not performed, the muscle under contraction still expends energy in counteracting the other force. Isometric contraction provides for a holding exercise, which is neither positive or negative. A third type of contraction is eccentric contraction. A simple example is the lowering of a weight to its rest position. In eccentric contraction, the weight is decelerated and the total work performed is negative because the muscle absorbs energy in decelerating the weight. Therefore, negative exercise is performed by eccentric contraction. In eccentric contraction, muscle is lengthened from its contracted or previously contracted position. That is, the muscle is being lengthened by a load or a force greater than the muscle’s holding force.

[0122] In a concentric contraction exercise, positive strength is used in which the muscle is shortened against a force or resistance, such as in lifting a weight. In a concentric exercise system, also called a positive exercise system, an object is moved by the muscular contraction, such as by lifting, so that it will cause the muscle to expend energy and this energy is stored in the object. In this instance, the lifting force of the muscle must exceed the resistive force of the object. When the force exerted by the muscle equals the weight of the object, this holding strength of the muscle provides the isometric contraction. In an isometric contraction, no movement occurs but energy is expended by the muscle.

[0123] An eccentric exercising involving negative strength will occur when the force exerted by the muscle is less than the resistive force of the object, which was previously lifted. As the object is lowered, the potential energy stored in the object is converted to kinetic energy and absorbed by the muscle. The muscle lengthens from the previously contracted position. An eccentric exercise system is based on a force overcoming a contracted muscle. That is, the force (weight) is greater than the muscle’s holding force.

[0124] It is generally known that not only is the direction of exercise important, but emphasis is placed on the type of resistive force (or load) opposing the muscle to be exercised. An eccentric load provides a stretching or pulling force against the contracting muscle and can occur during positive or negative exercise stroke. An eccentrically loaded exercise system is one in which an object moved by the muscular contraction stores this energy, not merely dissipating it, that is the exercise system possesses potential energy which is available to do work on the contracted muscle whenever the muscle force becomes less than the force supplied by the exercise machine.

[0125] In actual life, the combination of eccentric and concentric contractions operate together, such as when lifting and lowering a weight. Further, the combination of eccentric and concentric contractions form a natural type of muscle function called a “stretch-shortening cycle”. The stretch-shortening cycle allows the concentric contraction to take place with greater force or power output, as compared to initiating a movement by concentric contraction alone. This phenomenon is believed to occur partly due to the elastic nature of the muscle during and immediately after the eccentric contraction. The lengthening of the contracted muscle modifies the condition of the muscle such that the stretched muscle increases its tension and stores potential energy. Part of this stored energy can be recovered provided that the concentric contraction occurs rapidly after the eccentric contraction.

[0126] Further, in comparing negative exercise to positive exercise, negative only exercise produces at least as much, if not greater, muscle growth than positive only exercise. Strength increase of as much as 40% has been documented by the use of negative exercise (Ettigton Darden; The Nautilus Bodybuilding Book; Chapters 13-14; Contemporary Books, Inc.; 1982). Furthermore, the negative exercise provides other advantages, such as stretching for the improvement of flexibility; pre-stretching for high-intensity muscular contraction; resistance in the position of full contraction for full range exercise; and maximum application of resistance throughout a full range of possible movement.

[0127] Muscles can generate more force eccentrically than concentrically, whilst superimposed vibration enables a user to lift a smaller weight than would have been the case without vibration, the muscle responding as if a much heavier weight had been lifted. This means that an exercise machine can be somewhat safer, with less risk of injury, when superimposed vibration is incorporated, merely because lighter weights can be employed. Additionally, imposing a vibration during an eccentric phase can have greater effects than during the concentric phase for stimulation of the neuromuscular system, leading to greater training adaptations, i.e. strength. This can all be particularly important in use by rehabilitation, elderly and clinical populations where small weights can be lifted. From a mechanical viewpoint additional vibration stimulation can lead to a more efficient return of a weight to the rest configuration.

[0128] Accordingly, providing an additional resistance and vibration during a lowering, eccentric phase can be very beneficial for health and performance. This has implications for injury prevention and recovery, clinical populations and sports performance.

[0129] The embodiment shown in FIG. 28 comprises a double ended cylinder 800, a piston 801 therein associated with a shaft 802, a hydraulic fluid conduit 803 connected into both ends of the cylinder 800, a rotary valve 804 having a valve core 804a and sited in the conduit 803 and driven by a motor 805, a motor variable speed control 806 and a bleed valve/filler point 807 arranged for loading the circuit with hydraulic fluid and bleeding air from the conduit 803. There is accordingly a closed circuit filled with fluid—typically a conventional glycol, silicone or other similar liquid based
hydraulic fluid. The fluid flow is therefore interrupted by the rotation of the valve core 804a as the ports are cyclically revealed and closed.

[0130] The electric motor 805 provides mechanical rotation to the valve core, the rotational speed being controlled by variable speed control 306.

[0131] A preferred embodiment employs a stepper motor as the electric motor 805 with the speed controller switching coils of the stepper motor providing an accurate and controlled rate of rotational speed proportional to the frequency of the power signals applied to the stepper motor field coils, the number of field coils and the number of poles in the rotor.

[0132] Other motors and control means are possible.

[0133] The variable speed control 806 can be pre-set at manufacture, set for a particular training session type or machine type, set for a particular training regime associated with a user exercise profile and be interactive depending on feedback sensors measuring such parameters as applied force, load—e.g., weights—setting, rate of work, time duration of exercise or other appropriate measured individual user exercise or machine parameters.

[0134] A preferred embodiment of the speed controller 806 employs a microprocessor based electronic hardware and software solution to machine control that permits the described interactive system to respond in real-time to user and sensor inputs. The system may employ an embedded microcontroller or a PC based solution, with a software application providing user or system manager programming through a software user interface, interaction and response depending on user and sensor inputs and stored programme control.

[0135] Specific embodiment forms are envisaged such that variants of this vibrational load system may be retro-fitted to a plurality of current gym load-training equipment or be incorporated into new-design systems employing essentially current product forms as well as completely new mechanisms designed to specifically exploit the specific attributes of vibrational training.

[0136] The shaft 802 is directly or indirectly coupled to the mechanism of gym equipment including normal weights or other forms of load application retained through cables, linkage mechanisms, gears or other established means.

[0137] When a user moves a weight on a weights machine or performs other similar load stressing, the muscle group involved recruits muscle fibre to perform the work, dropping fibres as they become exhausted and recruiting further muscle in replacement over time. Typically only a proportion of the muscle fibre is engaged at any one time, thus it takes some time to exercise all of the muscle group one wishes to strengthen.

[0138] The "tendon-tap" response is a well known physiological behaviour whereby frequent cyclical application and removal of a small load cannot be distinguished from a continuously increasing load. The body responds by continuing to recruit muscle for as long as the cyclical load is applied. The application of vibration in this invention accordingly allows more rapid recruitment and exercise of the majority of a muscle group compared to conventional training means. Also, as the majority of muscle in any target group in engaged, the likelihood of muscle damage through over-work is minimized and greater weight or frictional loads may be applied.

[0139] In this embodiment the user works against a normal load such as lifting a weight or working against a frictional load mechanism. This engages muscle fibre from the specific target muscle group or groups involved. In addition, the user is attempting to move the piston 801 through the cylinder 800. When rotary valve 804 with valve core 804a is open this action displaces fluid around the circuit to fill the opposite chamber of the cylinder with little or no appreciable level of resistance. However, when the valve core 804a has rotated to close the valve ports the user is attempting to compress an essentially incompressible fluid and perceives a reactive load directly proportional to that applied by the user in attempting to create further motion.

[0140] As the valve core 804a is rotating and the ports are cyclically opened and closed the user perceives an alternating resistance to motion which invokes the tendon-tap response by their body, recruiting greater percentages of muscle fibre compared to conventional weights or other linear load application methods.

[0141] The frequency of the perceived resistance with a simple on-axis rotating valve core 804a (as shown) will be at double the rotational frequency of the valve core. More cross ports in the valve core will proportionally increase the effective resistance frequency while an offset valve core configured as shown in figure will present a 1:1 relationship between the valve-core rotational speed and perceived load frequency.

[0142] An efficacious applied load frequency has been determined by experiment to be between 1 Hz and 100 Hz but is preferably between 15 Hz and 50 Hz. As the human body increasingly dampens the amplitude of the load applied as the frequency increases, it becomes progressively harder to translate a reactive force at >35 Hz. However, below about 10 Hz the tendon tap response fails to occur due to the normal repeat speed of neurological signalling within the human body. The load application mechanism also creates some damping such that the stiffer the mechanism between the user and the piston, the more force will be effected.

[0143] The described system operates through frequency modulation of the applied load. The amplitude of the load, with the noted caveat about damping factors, is also determined by how fast and hard the user attempts to operate the machine.

[0144] Conventional known frictional and load application methods are amplitude modulated through either variable weights, variable leverage ratios, variable fluid flow apertures or variable frictional control mechanisms.

[0145] Various modifications to the embodiment described with reference to FIG. 28 may be envisaged. For example, as shown in FIG. 29, a release mechanism comprising a one-way valve 810 bypasses the cylinder 800 such that in a typical weights machine configuration, the vibration system only applies a load in the lift direction and allows free descent of the piston and hence the operating lever, in the weight “falling” direction.

[0146] In the orientation shown in FIG. 29 the one-way valve is shut when the operating rod 802 moves the piston 801 UP forcing fluid through the rotary valve 804. However when the operating rod 802 is moved DOWN the fluid flow reverses and bypasses the rotary valve 4 through the one way valve 810.

[0147] When connected to the mechanism of exercise equipment—typically a leg extension machine—the expected configuration would be such that when lifting a weight or working against a spring load or other resistive means the operating rod 802 moves UP in the orientation
shown in the diagram providing the described pulsing additional load, whilst when lowering the weight the one way valve V10 operates and permits free release of the weights and mechanism allowing to return to its start position without significant resistance.

[0148] Several rotary valves operating in parallel at different constant frequencies to create specific harmonic frequencies, or to create synthesised approximations to square wave, sine wave, sawtooth wave or other pulse shapes through addition techniques or pseudo random frequencies through frequency modulation of the valve speeds.

[0149] An in-circuit variable aperture valve is possible to set the level of fluid flow resistance controlling the amplitude of the vibratory reaction force.

[0150] Computer or microcontroller management or a combination thereof is also possible to create sophisticated FM and AM load control.

[0151] The embodiment illustrated in FIG. 30 comprises the cylinder 800 and piston 801 and shaft 802, the conduits 803, the rotary valve 804 (and the filler/bleed 807—not shown), and the one way valve 810, together with an hydraulic pump 811 and a pressure switch 812. In this instance the pump 811 and the one way valve 810 are in series with the rotary valve 804 and in parallel with each other.

[0152] In the orientation shown in FIG. 30, as the operating rod 802 is moved UP and the piston 801 displaces fluid from the top of the cylinder 800 it will flow through the one way valve 810 and be subject to pulsed interruptions effected by the rotary valve 804.

[0153] In one embodiment of the system illustrated in FIG. 30 the rotary pump 811 is continuously pushing fluid in a clockwise loop also passing through the one way valve 810 and does not essentially disrupt or affect the flow of fluid from the cylinder 800 through the rotary valve 804 and thence to the lower part of the cylinder 800 completing the fluid circuit and introducing the previously described pulsed load.

[0154] However on the downward stroke of the operating lever 802 and the piston 801, fluid flow in the main circuit is reversed, passing from the lower part of the cylinder 800, through the rotary valve 804 until it reaches the valve side junction of the rotary pump 811 and the one way valve 810 and is pumped by the rotary pump 811. If the pump flow rate is set higher than the natural unaided return flow rate a positive pressure will be felt by the user moderated by the pulsing caused by the rotary valve 804.

[0155] In another embodiment of the system illustrated in FIG. 30, to prevent any flow issues in the one way valve 810 and the rotary pump 811 fluid circuits, the pump 811 may be switched OFF when the piston 801 is on the UP stroke and flowing through the one way valve 810. While this is occurring there will be a NEGATIVE pressure below the piston. Upon lowering the operating rod 802 and hence the piston 801 a POSITIVE pressure will be generated below the piston 801 that may be used to turn on the pressure operated switch 812 in this arm of the fluid circuit that may be used to turn ON the rotary pump 811 to generate an excess downwards force on the piston 801, moderated by the pulsing effect of the rotary valve 804.

[0156] To effect an additional force on the downward stroke of the piston/operating rod in circuit configurations of a similar nature to those shown in particular in FIG. 30 one discriminates between flow directions and pressures within the circuit in order to employ specific components that may create excess pressure and enhance flow only on the downward stroke. Typically the apparatus applies up to a 120% increase in the load during the eccentric part of a weight lifting cycle, preferably 50-120%.

[0157] In the embodiment shown in FIG. 30 as just above described two elements are potentially used:

1. A one way valve 810 that discriminates fluid flow directions—and hence operational—flow DIRECTION to create different circuit forces on the piston 801 and hence on the operating rod 802 and user exercise mechanism dependent on user interaction with these component parts. The rotary pump 811 is allowed to continue rotating at all times, but is provided with a circular fluid flow route to prevent this creating forces at the wrong time. The balance of fluid flows may however prove to be difficult to control to a satisfactory level of accuracy with such a simple system.

2. A second embodiment that combines the first embodiment described above with a pressure switch 812 that detects the pressure change associated with a reversal of the equipment operation solves some of these issues by turning off the rotary pump 811 when not required—for example for the UP stroke and on again when on the down stroke.

[0158] It is then obvious to one skilled in the art that enhanced control options may be effected by replacement of the pressure switch with a pressure transducer and that would allow proportional control of the pump and hence more precise control of the system.

[0159] Other sensors such as fluid flow sensors may be employed to detect additional parameters to facilitate more sophisticated control means.

[0160] Embedded Microprocessor or PC systems may be employed to provide complex software management of the system performance and interactive control means.

[0161] The system illustrated in FIG. 31 is similar to that of FIG. 30 but contains a flow control valve 813 to adjust the amount of permissible bypass fluid compared to flow into the top of the cylinder 800. Control of the valve 813 may be preset or interactive, typically triggered by a pressure switch 812 and through a control algorithm running on a microprocessor controller device (not shown) to give more sophisticated interactive control, typically using an analogue pressure sensor in place of the switch 812. This embodiment, therefore, permits fine adjustment of the fluid flow paths and hence the delivered force experienced by the user on the downward stroke of the piston 801.

[0162] The system illustrated in FIG. 32 represents a yet further development, taking as its starting point the system illustrated in FIG. 31, with like numbers representing the same elements. However also incorporated in the hydraulic circuit is a flow sensor 814. The figure also illustrates items which are also likely to be associated with the systems illustrated in FIGS. 29-31, namely a pivoted lever 820 associated with the shaft 802, a cable 821 and pulley system 822 and weights 823, an input/output (I/O) level and power interface 824 and a user interface and display 825. The I/O level and power device 824 interfaces between the motorised valves 813, pump 811, rotary valve 804 (outputs) and flow 814 and pressure 812 sensors (inputs) to the up (computer) system containing system firmware, operational software with any algorithms controlling hardware interactions under program control and interactions with the user entered through a User Interface (UI). This enables real-time interactions as well as pre-programmed performance characteristics.
Via the User Interface and display 825 the user can select operating modes such as:

Resistance in up and down activation modes
Vibration frequency in up and down vibration modes
Pressure and Flow threshold trigger or mapping between applied load (user) and the machine

In the systems illustrated in FIGS. 33 and 34 the system of actual weights is replaced by a compressible system, particularly a gas system.

Referring to FIG. 33, when the lever 850 is moved DOWN the piston rod 851 attached to the piston 852 is moved up in the cylinder 853 displacing fluid 854 through the rotary valve 855 driven by the motor 856 that creates a cyclical checking force at it rotates and presents an open then closed port to the fluid 854. The fluid 854 then passes through a variable flow control valve 857 that provides a controllable resistance to flow that the user must work against and thence through a one way valve 858 into the top chamber 859 of a pressure vessel 860. The increased volume of fluid displaces the moveable separator 861, typically a sliding piston or diaphragm, to compress a compressible medium, typically air or nitrogen gas or a mechanical spring or alternatively a lifted weight or other mechanical configuration storing energy.

A vent 862 is provided under the piston to permit free motion without development of over or under pressures beneath the piston 852.

Applied pressure may pass back through the one way valve 863 and variable flow control valve 864 but fluid flow is checked by the upward motion of the piston 852 and forward flow of fluid induced by the force created by the user at the lever 850.

When the user stops moving the lever 850 DOWN there is an over-pressure in the compressible medium contained in lower chamber 865 of the pressure vessel 860 that displaces the moveable separator 861 UP moving fluid from the upper chamber 859 through the one way valve 863 and the variable flow control valve 864 via the rotary valve 855 that provides a similar alternating cyclical flow characteristic to that provided during the previously described downward motion of the Lever 1. Thus the piston 852 is pushed DOWN and the user must work against this force as the lever returns upwards to its original position.

FIG. 33 shows separate variable flow control valves 857 and 864 in the two halves of the circuit such that in co-operation with the one way valves 858 and 863 different flow resistances may be set for each direction of lever travel thus varying the imposed load on the user.

The benefits of this system over conventional physical training devices are:

The fluid flow resistances may be easily altered to suit different users and training regimes;
The upward and downward strokes of the machine may be altered to provide differing perceived loads to provide an enhanced symmetrical training effect on the loaded muscle groups;
The vibrational component introduced by the provision of a motor driven rotary valve 855 enhances the training effect and muscle recruitment as described above.

Referring to FIG. 34 the configuration is generally the same as in FIG. 33 but a slide valve 870 has been substituted for the two one way valves 858, 863.

In this embodiment, downward motion of the lever 850 moves the piston 852 upwards in the cylinder 853 displacing fluid 854 through the rotary valve 855 driven by the motor 856 thus inducing a cyclical checking force to the fluid flow, perceived by the user as a vibratory load. In the phase of operation shown in FIG. 34 fluid may pass through the upper valve port 871 of the slide valve 870 due to the position of the Slide Valve Core 872.

The variable flow control valve 857 restricts fluid flow in this part of the circuit relating to an upward stroke of the piston 852 and may be controlled to provide a variable perceived resistance to motion in this direction at the lever 850.

Fluid is then forced into the pressure vessel 860 upper chamber 859, displacing the moveable separator 861 and thus compressing the compressible medium in the lower chamber 865. However, in this embodiment, pressure is not transmitted back to the user through the variable flow control valve 864 but is checked by the closed lower valve port 873 of the slide valve 870.

When the piston 852 reaches the top of its stroke it strikes the upper operating rod 874 that moves the slide valve core 872 via the upper linkage 875 and the upper valve linkage 876. This closes the upper valve port 871 and opens the lower valve port 873 enabling fluid flow from the pressure vessel 860 upper chamber 859 through the variable flow control valve 864, driven by the stored pressure in the compressible medium in the lower chamber 865 and transmitted through the moveable separator 861. The returning displaced fluid passes through the rotary valve 855 driven by the motor 856 to provide a vibratory checking effect and downward force on the piston 852.

It will be noted that as the lower linkage 877 and the upper linkage 875 are connected to the slide valve core through the lower valve linkage 878 and the valve upper linkage 876 respectively the changing of the slide valve core 872 position through the piston 852 striking the upper operating rod 874 also moves the lower linkage 877 and thus the lower operating rod 879, moving this into the cylinder 853.

When the piston 852 reaches the bottom of its stroke it strikes the projecting tip of the operating rod 879 resetting the system to its original configuration as shown in FIG. 34, resetting the slide valve 872 to allow recharging of the pressure vessel 860 by means described above.

An advantage of the embodiment shown in FIG. 34 compared to that of FIG. 33 is that the back pressure, and therefore the loads, perceived by the user in either of the two main states of the machine, being dictated by the position of the slide valve 872 such that the variable flow control valves 857 and 864 do not interact at any phase of the operation, may be more precisely controlled for optimal load conditions applied to the user.

Pressure and flow sensors, motorised control valves and variable motor speed controls may be substituted for manual control and a fixed speed rotary valve motor to permit interactive control by a microprocessor system and software algorithm to provide fine-control over each phase of the system operation including parameters such as:

Flow Resistance
Flow Rate
Vibration Frequency
To one skilled in the art, additional features may be envisaged such as a safety pressure release valve fitted to the lower chamber 865 of the pressure vessel 860, a variable
volume lower chamber 865 set by an additional moveable piston or diaphragm arrangement to control the amount of stored energy in the pressure vessel and the relationship between the fluid volume and the compressible medium volume if a gas is employed, a microprocessor and software or mechanically controlled variable linkage to a weights or spring mechanism. Similarly the operating rods 874 and 879 may be replaced by Hall Effect sensors triggered by magnets in the piston 852 associated with amplifiers or by other sensor and valve operation means to open and close a pair of solenoid or other electrically driven valves in place of the slide valve 872 and relating to the position of the piston 852 and these may be incorporated into a control system operated by a microprocessor employing a software control algorithm.

[0190] As described above with reference to FIG. 25 the systems described with reference to FIGS. 28 to 34 may be programmed to be adaptable to a specific training regime and store and modify the program automatically according to the performance of the user as detected by the fitted system sensors.

1-49. (canceled)

50. A muscle training apparatus arranged for cyclic concentric and eccentric loading phases and comprising:
load imposition means arranged for a user to exercise against;
load variation means arranged for varying the load as between concentric and eccentric loading phases;
a vibrator operational to apply vibration between the user and the load, and
a controller operational to control the vibrator and to vary the extent of vibration as between concentric and eccentric phases.

51. A muscle training apparatus arranged for cyclic concentric and eccentric loading phases and comprising:
load imposition means operational to impose a load upon muscles of a user; and
an hydraulic system operational to increase the imposed load during the eccentric phase.

52. A muscle training apparatus as claimed in claim 50 and further comprising an hydraulic piston/cylinder arrangement operationally interposed between a user and the load imposition means.

53. A muscle training apparatus as claimed in claim 51 and further comprising an hydraulic piston/cylinder arrangement operationally interposed between a user and the load imposition means.

54. A muscle training apparatus as claimed in claim 50 and operational to impose an increase during the eccentric phase of up to 120% of the load moved in the concentric phase.

55. A muscle training apparatus as claimed in claim 51 and operational to impose an increase during the eccentric phase of up to 120% of the load moved in the concentric phase.

56. A muscle training apparatus as claimed in claim 50 and wherein the vibration frequency is from 1 Hz to 100 Hz.

57. A muscle training apparatus as claimed in claim 50 and wherein the vibrator is a rotary valve.

58. A muscle training apparatus as claimed in claim 50 and wherein the vibration control is operational to vary the vibration randomly.

59. Apparatus as claimed in claim 52 and having a bleed through said piston.

60. Apparatus as claimed in claim 52 and further comprising a non-return valve enabling a different resistance to be obtained as between tensile and compression movement.

61. Apparatus as claimed in claim 52 and further comprising a pressure relief valve located in said piston.

62. Apparatus as claimed in claim 50 and arranged to load the user in both directions, push and pull, compression and tension.

63. Apparatus as claimed in claim 50 and which is portable for use in one hand or between a user’s two hands for arm strengthening and “chest expanding”.

64. Apparatus as claimed in claim 50 and equipped with an indicator of the load being applied.

65. Apparatus as claimed in claim 50 and further comprising a non-return valve arranged to enable the load to differ as between the two directions.

66. Apparatus as claimed in claim 65 and further comprising a control cock arranged to block or open said non-return valve and convert the apparatus between unidirectional and bi-directional strength training.

67. Apparatus as claimed in claim 50 and wherein said vibrator comprises a solenoid valve.

68. Apparatus as claimed in claim 57 and wherein said rotary valve comprises (i) a housing containing a fluid flow path with a central axis, (ii) a plug having a sealing face cooperating with said housing in the closed position to block the fluid path, and (iii) a support shaft arranged to carry said plug means and being rotatable on an axis which is normal to and spaced from the axis of said valve seat and located outside the flow path so that rotation of the said shaft moves said plug means relative to said housing.

69. Apparatus as claimed in claim 57 and wherein said valve is arranged to permit a small throughput of fluid thorough when the valve is ostensibly closed.

70. Apparatus as claimed in claim 50 and which is a muscle strengthening apparatus having a bar arranged for bearing upon the lower part of a user’s arms whereby the user moves said bar against an adjustable weight.

71. Apparatus as claimed in claim 50 and wherein said vibration is arranged to be aligned with the direction of loading.

72. Apparatus as claimed in claim 50 and wherein the direction of vibration is adjustable.

73. Apparatus as claimed in claim 50 and further comprising a data entry device arranged for programming the operation thereof.

74. Apparatus as claimed in claim 50 and further comprising a readout device arranged for indicating the weight and/or vibration applied and the amplitude of apparatus expansion or compression.

75. Apparatus as claimed in claim 53 and wherein said vibration facility comprises a rod carrying a helix and a disc held to said piston and mounted on said rod so that movement of said piston along said cylinder causes said disc to rotate, there being channels through said piston and said disc which are thereby intermittently aligned.

76. An exercise apparatus comprising:
resistance means arranged to provide adjustable resistance to a movement by a user;
vibration means arranged to impart a vibration to the user’s muscle or muscle group being exercised;
an input device arranged for converting an input signal into controls for said resistance means and said vibration means;
an output device arranged to provide an indication of the program completed; and wherein
said vibration means comprises a piston, connecting rod and cylinder arrangement and a fluid flow connection between both sides of the piston and at least one valve interposed in said fluid flow and arranged for intermittent opening and closing at a frequency between 1 Hz and 100 Hz; and

said resistance means is selected from free weights, a weight machine, a spring resistance, an hydraulic resistance and a pneumatic resistance.

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