The invention comprises a method and/or an apparatus using computer-configured exercise equipment and an electric motor. A computer-controlled robotic resistance system is used for training, diagnosis and/or therapy. The resistance system comprises: a subject interface, software control, a controller, an electric servo assist/resist motor, an actuator, and/or a subject sensor. The system overcomes the limitations of the existing robotic rehabilitation, weight training, and cardiovascular training systems by providing a training and/or rehabilitation system that adapts a resistance or force applied to a user interactive element in response to the user's interaction with the system, a physiological strength curve, and/or sensor feedback. For example, the system optionally provides for an automatic reconfiguration and/or adaptive load adjustment based upon real time measurement of a user's interaction with the system or sensor based observation by the exercise system as it is operated by the subject.
Linear Movement

Distance (arbitrary)

Resistance

Rotational Movement

Rotational Angle (degrees)

FIG. 3

FIG. 5
ROTARY EXERCISE EQUIPMENT
APPARATUS AND METHOD OF USE
THEREOF

CROSS-REFERENCES TO RELATED
APPLICATIONS

[0001] This application:
[0002] is a continuation in part of U.S. patent application
Ser. No. 12/545,324, filed Aug. 21, 2009, which under
35 U.S.C. 120 claims benefit of U.S. provisional patent
application No. 61/091,240 filed Aug. 22, 2008; and
[0003] claims benefit of U.S. provisional patent application
No. 61/387,772 filed Sep. 29, 2010,
[0004] all of which are incorporated herein in their
entirety by this reference thereto.

STATEMENT REGARDING FEDERALLY
SPONSORED RESEARCH OR DEVELOPMENT

[0005] The U.S. Government may have certain rights to
this invention pursuant to NASA SBIR Contract number:

BACKGROUND OF THE INVENTION

[0006] 1. Field of the Invention
[0007] The present invention relates generally to computer
and motor assisted exercise equipment methods and apparatus.
[0008] 2. Discussion of the Related Art
[0009] Patents related to computer controlled variable
resistance exercise equipment are summarized herein.

Sensors and Resistive Force

Mechanism for Exercise Machines”, U.S. Pat. No. 5,015,
926 (May 14, 1991) describes an exercise machine equipped
with a constant speed electric drive mechanically coupled
to a dynamic clutch, which is coupled to an electromagnetic
coil or fluid clutch to control motor force input. An electronic
sensor connected to a computer senses the speed, motion,
and torque force of the system’s output shaft and a control unit
directed by the computer controls the clutch.

Machine”, U.S. Pat. No. 4,869,497 (Sep. 26, 1989) describe
a computer controlled exercise machine where the user selects
an exercise mode and its profile by programming a computer.
Signals are produced by the program to control a resistive
force producing device. Sensors produce data signals corre-
spending to the actuating member of the system, velocity
of movement, and angular position. The sampled data are used
to control the amount of resistive force.

Pressure/Movement Sensors

[0012] M. Mariakka, et. al., “Method and Device for Meas-
uring Exercise Level During Exercise and for Measuring
Fatigue”, U.S. Pat. No. 7,764,990 B2 (Jul. 27, 2010) describe
sensors for measuring electrical signals produced by muscles
during exercise and use of the electrical signals to generate a
fatigue estimate.

Assessment System”, U.S. Pat. No. 7,470,216 B2 (Dec. 30,
2008) describe an intra-repetition exercise system comparing
actual performance to a pre-established goal with each rep-
etition of the exercise, where displayed indicia includes travel
distance and speed.

Measuring Pressure Exerted During Aquatic and Land-Based
Therapy, Exercise and Athletic Performance”, U.S. Pat.
No. 5,258,927 (Nov. 2, 1993) describe a device for monitoring
exercise pressure on systems using an enclosed compressible
fluid chamber. Measurements are taken at pressure ports and
are converted to a digital signal for computer evaluation of
type and degree of exercise performed.

Hand Controls

[0015] S. Owens, “Exercise Apparatus Providing Resis-
tance Variable During Operation”, U.S. Pat. No. 4,934,692
(Jun. 19, 1990) describes an exercise device having a pedal
and hand crank connected to a flywheel provided with a
braking mechanism. To vary the amount of braking, switches
located on the hand crank are used making removal of the
hand from the crank unnecessary to operation of the switches.

Resistance/Varying Resistance Exercise

[0016] D. Munson, et. al., “Exercise Apparatus Based on a
Variable Mode Hydraulic Cylinder and Method for Same”,
U.S. Pat. No. 7,762,934 B1 (Jul. 27, 2010) describe an exec-
time machine having a hydraulic cylinder sealed with spool
valves adjustable to permit entrance and exit of water with
forces corresponding to forces exerted on the cylinder.

[0017] C. Hulls, “Multiple Resistance Curves Used to Vary
Resistance in Exercise Apparatus”, U.S. Pat. No. 7,682,295
B2 (Mar. 23, 2010) describes an exercise machine having
varying resistance based on placement of a cable pivot point
within a channel, where placement of the pivot point within
the channel alters the resistance pattern along the range of
motion of an exercise.

Adjustment of Exercise Apparatus”, U.S. Pat. No. 7,645,212
B2 (Jan. 12, 2010) describe an electronic interface allowing
adjustment of speed and grade level via a computer based
interface mounted on an exercise machine, such as on a tread-
mill.

[0019] M. Anjanappa, et. al., “Method of Using and Appa-
ratus for Use with Exercise Machines to Achieve Programmable
Variable Resistance”, U.S. Pat. No. 5,583,403 (Dec.
10, 1996) describes an exercise machine having a constant
torque, variable speed, reversible motor and associated
clutches. The motor and clutch are chosen in a predetermined
combination through use of a computer controller.

U.S. Pat. No. 5,409,435 (Apr. 25, 1995) describes a program-
nable variable resistance exercise device providing a resis-
ting force to a user supplied force. The user supplied force is
resisted by varying the viscosity of a variable viscosity fluid
that surround plates rotated by the user applied force. A gear
and clutch system allow resistance to a pulling force.

for an Exercise, Physical Therapy, or Rehabilitation Appara-
tus”, U.S. Pat. No. 5,362,298 (Nov. 8, 1994) describe an
exercise apparatus having a cable connected to a resistive
weight and a detachable handle connected to the cable via a
tension transmitting device.

Physiological Response

Response to Foot Impact Induced Speed Variation”, U.S. Pat.
No. 5,476,430 (Dec. 19, 1995) describe an exercise treadmill having a plurality of rates of restoration of the tread belt speed upon occurrence of change in the load on the moving tread belt resulting from the user’s foot plant, where the user can select a desired rate of response referred to as stiffness or softness.

Power Generation/Energy Consumption


STATEMENT OF THE PROBLEM

[0026] While a wide variety of computer-controlled exercise machines for training and rehabilitation exist, some of which can be automatically adjusted to vary resistance or incline, such systems provide for preprogrammed changes in load or resistance.

[0027] What is needed is a system that overcomes the limitations of the existing robotic rehabilitation systems by providing a training and/or rehabilitation system that adapts a resistance or force applied to a user interactive element in response to the user’s interaction with the user interactive element, the system, and/or observations of the user by the system.

SUMMARY OF THE INVENTION

[0028] The invention comprises a computer assisted exercise equipment method and apparatus.

DESCRIPTION OF THE FIGURES

[0029] FIG. 1 provides a block diagram of an electric motor resistance based exercise system;

[0030] FIG. 2 illustrates hardware elements of an exemplary computer aided motorized resistance exercise system;

[0031] FIG. 3 provides exemplary resistance profiles for a linear movement;

[0032] FIG. 4 illustrates a rotary exercise system configured with electric motor resistance;

[0033] FIG. 5 provides exemplary resistance profiles for a rotary movement; and

[0034] FIG. 6 illustrates a combined linear and rotary exercise system.

DETAILED DESCRIPTION OF THE INVENTION

[0035] The invention comprises a method and/or an apparatus using a computer and rotary exercise equipment configured with an electric motor.

[0036] In one embodiment, exercise equipment configured with a rotatable crank and means for varying resistance to rotation of the rotatable crank using an electric motor is described.

[0037] In another embodiment, exercise equipment is configured with an electric motor resistance system. Resistance to movement supplied by the electric motor optionally varies dependent upon input from one or more subject sensors. Variation in resistive force optionally occurs:

[0038] within a single direction of a weight training repetition;

[0039] between directions of a weight training repetition; and/or

[0040] between repetitions within a single set of repetitions.

[0041] Herein, a repetition is one complete movement of an exercise and repetitions refers to the number of times each exercise is completed in a row or in a set.

[0042] In yet another embodiment, a computer-controlled robotic resistance system or mechanical resistance training system is used for:

[0043] strength training;

[0044] aerobic conditioning;

[0045] low gravity training;

[0046] physical therapy;

[0047] rehabilitation; and/or

[0048] medical diagnosis.

[0049] The resistance system comprises: a subject interface, software control, a controller, an electric motor, an electric servo assist/resist motor, a variable speed motor, an actuator, and/or a subject sensor. The resistance system is adaptable to multiple configurations to provide different types of training, as described infra.

[0050] The resistance system significantly advances neuromuscular function as it is adaptable to a level of resistance or applied force. For example, the system optionally uses:

[0051] biomechanical feedback

[0052] motorized strength training;

[0053] motorized physical conditioning; and/or

[0054] a computer programmed workout.

[0055] For example, a system is provided that overcomes the limitations of the existing robotic rehabilitation, weight training, and cardiovascular training systems by providing a training and/or rehabilitation system that adapts a resistance or force applied to a user interactive element in response to:

[0056] the user’s interaction with the training system;

[0057] a physiological strength curve;

[0058] sensor feedback; and/or

[0059] observations of the system.

[0060] For instance, the system optionally provides for an automatic reconfiguration and/or adaptive load adjustment based upon real time measurement of a user’s interaction with
the system or sensor based observation by the exercise system as it is operated by the subject 110.

DEFINITIONS

[0061] Herein, the human or operator using the resistance system is referred to as a subject. The subject is any of: a trainer, a trainee, a lifter, and/or a patient.

[0062] Herein, a computer refers to a system that transforms information in any way. The computer or electronic device, such as an embedded computer, a controller, and/or a programmable machine, is used in control of the exercise equipment.

[0063] Herein, an x-axis and a y-axis form a plane parallel to a support surface, such as a floor, and a z-axis runs normal to the x-y-plane, such as along an axis aligned with gravity. In embodiments used in low gravity space, the axes are relative to a support surface and/or to the subject 110.

Motor Assisted Resistance System

[0064] Referring now to FIG. 1, a block diagram of a motor equipped exercise system 100 is provided. As the exercise system 100 optionally provides resistance and/or assistance to a motion of user interface, such as a weightlifting bar or crank system, the motor equipped exercise system 100 is also referred to as a motor equipped resistance system, a resistance system, a motor equipped assistance system, and/or an assistance system. For clarity of presentation, examples provided herein refer to a resistance provided by a motor of the exercise system 100. However, the motor of the exercise system 100 is alternatively configured to provide assistance. Hence, examples referring to motor supplied resistance are non-limiting and in many cases the system is alternatively reconfigured to use motor supplied assistance in the range of motion of a particular exercise.

[0065] Still referring to FIG. 1, the exercise system 100 includes one or more of: a computer configured with a program 120, a controller 130, an exercise element 140, and/or a sensor 150. The exercise system 100 is configured for use by a subject 110.

[0066] Still referring to FIG. 1, the subject 110:

[0067] enters a program 120 to the resistance system 100;

[0068] alters the resistance of the exercise system within a repetition;

[0069] alters the resistance of the exercise system between repetitions;

[0070] is sensed by sensors 150 in the resistance system; and/or

[0071] is recognized by the resistance system, such as through wireless means described infra.

[0072] The program 120 is optionally predetermined, has preset options, is configurable to a specific subject, changes resistance dynamically based on sensor input, and/or changes resistance based on subject input, described infra. The program 120 provides input to a controller 130 and/or a set of controllers, which controls one or more actuators and/or one or more motors of an exercise element 140 of the exercise system 100. Optional sensors provide feedback information about the subject 110 and/or the state of a current exercise movement, such as a position of a movable element of the resistance system, a force applied to a portion of the exercise system 100, the subject's heart rate, and/or the subject's blood pressure. Signal from the sensors 150 are optionally fed in a feedback system or loop to the program 120 and/or directly to the controller 130.

[0073] Optionally, active computer control is coupled with motorized resistance in the exercise system 100. The computer controlled motor allows for incorporation of progressive and reconfigurable procedures in strength training, physical conditioning, and/or cardiovascular exercise. For example, computer control of the motor additionally optionally provides resistance curves overcoming the traditional limits of gravity based freestyle weightlifting, described infra.

Linear Movement

[0074] Referring now to FIG. 2, a linear movement system 200 is illustrated, which is a species of the exercise system 100. The linear movement system 200 is illustrative in nature and is used for facilitating disclosure of the system. Further, the species of the linear movement system 200 is to a specific form of the exercise system 100. However, the illustrated linear movement system 200 is only one of many possible forms of the exercise system 100 and is not limiting in scope. Herein the linear movement system refers to a linear, about linear, or non-rotational movement of the user interface exercise equipment, such as a weightlifting bar, or to movement of a resistance cable.

[0075] Still referring to FIG. 2, an exemplary computer and motorized aided linear movement system 200 is provided. Generally, FIG. 2 illustrates examples of the structural elements 140 of the exercise system 100. In the illustrated linear movement system 200 includes:

[0076] a base 210, such as an aluminum extrusion or suitable material

[0077] an upright support member 212 affixed to the base;

[0078] a removable weightlifting bar 220 placeable into a guide element of the upright support member 212, or other geometry suitable for interfacing with the subject, such as a D-handle;

[0079] a first end of a resistance cable 230 affixed to the weightlifting bar 220;

[0080] a cable spool 242 affixed to a second end of the resistance cable 230;

[0081] a resistance cable, such as flexible metallic cable, a fibrous cord, an about 0.053" sheathed Kevlar cord, or an about ½" T-100 cord; and/or

[0082] an electric motor configured to provide resistance to movement of the weightlifting bar 220 through the resistance cable 230.

[0083] As configured, the subject 110 straddles the electric motor 240 and stands on the floor, base 210, and/or a foot support or cross-member 214 of the base 210. The subject 110 pulls on the removable weightlifting bar 220 and/or on hand grips 222 affixed or attached to the weightlifting bar 220. Movement of the weightlifting bar 220 is continuous in motion, but is illustrated at a first point in time, t1, and at a second point in time, t2, for clarity. The subject pulls the weightlifting bar 220, such as along the z-axis. Movement of the weightlifting bar 220 is resisted by the electric motor 240. For example, the electric motor 240 provides a resistive force to rotation of the cable spool 242, which transfers the resistive force to the resistance cable 230 and to the weightlifting bar 220 pulled on by the subject 110. In one example, the electric motor 240 includes a 10:1 or low lash gearbox and/or a
MicroFlex drive to control motor torque. The torque produced by the motor is optionally made proportional to an analog voltage signal applied to one of the drive’s analog inputs or is controlled by sending commands to set the torque value using a digital communications protocol.

Orientations

The linear movement system 200 is illustrated with the resistive cable 230 running in the z-axis. However, the resistive cable 230 optionally runs along the x-axis or any combination of the x-, y-, and z-axes. Similarly, the linear movement system 200 is illustrated for the user subject 110 standing on the floor. However, the exercise system 100 is optionally configured for use by the subject 110 in a sitting position or any user orientation. Further, the linear movement system 200 is illustrated with the subject 110 pulling up against a resistance. However, the subject is optionally pushing against a resistance, such as through use of a force direction changing pulley redirecting the resistance cable 230. Still further, the linear movement system 200 is illustrated for use by the subject’s hands. However, the system is optionally configured for an interface to any part of the subject, such as a foot or a torso.

Resistance/Assistance Profiles

Traditional weight training pulls a force against gravity, which is constant, and requires the inertia of the mass to be overcome. Particularly, a force, F, is related to the mass, m, moved and the acceleration, g, of gravity, and the acceleration of the mass, a, through equation 1,

\[ F = mg + ma \]  
(eq. 1)

where the acceleration of gravity, g, is

\[ g = 9.81 \text{ m/s}^2 \]

Hence, the resistance to movement of the weight is non-linear as a function of time or as a function of movement of the user interactive element.

Referring now to FIG. 3, resistance profiles 300 are illustrated, where both the resistance and distance are in arbitrary units. For traditional free weight strength training, the external resistance profile is flat 310 as a function of distance. For example, on a bench press a loaded weight of 315 pounds is the resistance at the bottom of the movement and at the top of the movement where acceleration is zero. At positions in between the external force required to accelerate the mass is dependent on the acceleration and deceleration of the bar. In stark contrast, the exercise system 100 described herein allows for changes in the resistance as a function of position within a single repetition of movement. Returning to the bench press example, it is well known that the biomechanics of the bench press result in an ascending strength curve such that one can exert greater force at the end of the range of motion than at the beginning. Hence, when the lifter successfully lifts, pushes, or benches through the “sticking point” of the bench press movement, the person has greater strength at the same time the least amount of force needs to exerted as the mass is decelerating resulting in the musculature of the chest being sub-optimally loaded. Accordingly, a variable resistance profile starting with a lower resistance and then increasing to a peak resistance is more optimal for a bench press.

Still referring to FIG. 3, still an additional profile 350 is a profile where the force at the beginning of the lift (in a given direction) is about equal to the force at the end of the lift, such as a weight of mass times gravity. At points or time periods between the beginning of the lift and the end of the lift (in a given direction) the force applied by the electric motor optionally depends on whether the bar is accelerating or decelerating. For example, additional force is applied by the motor during acceleration and no additional force is applied by the motor during deceleration versus a starting weight. For example, the applied force profile is higher than a starting weight or initial force as the load is accelerated and less than or equal to the initial load as it movement of the repetition decelerates.

Still referring to FIG. 3, more generally the resistance profile 300 is optionally set:

- according to predetermined average physiological human parameters;
- to facilitate therapy of a weak point in a range of motion;
- to accommodate restricted range of motion, such as with a handicap;
- to fit a particular individual’s physiology;
- to fit a particular individual’s preference;
- in a pre-programmed fashion;
- in a modified and/or configurable manner; and/or
- dynamically based on sensed values from the sensor 150; and/or
- through real-time operator 110 input.

Several optional resistance profiles are illustrated, including: a step-down function resistance profile 320, an increasing resistance profile 330, and a peak resistance profile 340. Physics based profiles include:

- accurate solution of \[ F = mg + ma \]  
- accurate solution of \[ F = mg + \begin{cases} ma, & (a > 0) \\ 0, & (a \leq 0) \end{cases} \]

which prevents the resistance from dropping below the baseline, static resistance; and/or

- accurate solution of \[ F = mg + \text{maximum}, \] which maintains the maximum resistance developed when accelerating the load through the remainder of the lift.

Additional profiles include a step-up profile, a decreasing resistance profile, a minimum resistance profile, a flat profile, a complex profile, and/or any permutation and/or combination of all or parts of the listed profiles. Examples of complex profiles include a first profile of sequentially increasing, decreasing, and increasing resistance or a second profile of decreasing, increasing, and decreasing resistance.

In one example, the resistance force to movement of the subject interface varies by at least 1, 5, 10, 15, 20, 25, 50, or 100 percent within a repetition or between repetitions in a single set.

Reverse Movement

For the linear movement system 200, resistance profiles were provided for a given direction of movement, such as an upward push on bench press. Through appropriate mounts,
pulleys, and the like, the resistance profile of the return movement, such as the downward movement of negative load of the bench press, is also set to any profile. The increased load is optionally set as a percentage of the initial, static load. For example, the downward force profile of the bench press are optionally set to match the upward resistance profile, to increase weight, such as with a an increased weight "negative" bench press, or to have a profile of any permutation and/or combination of all or parts of the listed profiles.

**Time/Range of Motion**

[0107] One or more sensors are optionally used to control rate of movement of the resistive cable. For example, the electric motor 240 is optionally configured with an encoder that allows for determination of how far the cable has moved. The encoder optionally provides input to the controller 130 which controls further movement of the actuator and/or motor turn, thereby controlling in a time controlled manner movement or position of the resistive cable.

[0108] In one example, the exercise system 100 senses acceleration and/or deceleration of movement of the movable equipment, such as the weightlifting bar 220. Acceleration and/or deceleration is measured using any of:

- an encoder associated with rotation of the electric motor;
- an accelerometer sensor configured to provide an acceleration signal; and/or
- a-priori knowledge of a range or motion of a given exercise type coupled with knowledge of:
- a start position of a repetition;
- a physical metric of the operator, such as arm length, leg length, chest size, and/or height.

[0114] Since putting an object into motion takes an effort beyond the force needed to continue the motion, such as through a raising period of a bench press, the forces applied by the motor are optionally used to increase or decrease the applied force based on position of movement of the repetition. The encoder, a-priori knowledge, physical metrics, and/or direct measurement with a load cell, force transducer, or strain gage are optionally used in formulation of the appropriate resistance force applied by the electric motor 240 as a function of time.

**Exercise Types**

[0115] Thus far, concentric and eccentric exercises configurable with the exercise system 100 have been described. Optionally, isometric exercises are configurable with the exercise system 100. An isometric exercise is a type of strength training where a joint angle and a muscle length do not vary during contraction. Hence, isometric exercises are performed in static positions, rather than being dynamic through a range of motion. Resistance by the electric motor 240 transferred through the resistive cable 230 to the weightlifting bar 220 allows for isometric exercise, such as with a lock on the motor or cable, and/or through use of a sensor, such as the encoder.

**Rotational Movement**

[0116] Thus far, the linear movement system 200 species of the exercise system 100 has been described. Generally, elements of the linear movement system 200 apply to a rotational movement system 400 species of the exercise system 100 genus. In a rotary movement system, the electric motor 240 provides resistance to rotational force.

[0117] Referring now to FIG. 4, a rotational movement system 400 is illustrated, which is a species of the exercise system 100. The rotational movement system 400 is illustrative in nature and is used for facilitating disclosure of the system. Further, the species of the rotational movement system 400 is to a specific form of the exercise system 100. However, the illustrated rotational movement system 400 is only one of many possible forms of the exercise system 100 and is not limiting in scope.

[0118] Still referring to FIG. 4, an exemplary computer and motorized aided rotational movement system 400 is provided. Generally, FIG. 4 illustrates examples of the structural elements 140 of the exercise system 100. In the illustrated system, the rotational movement system 400 includes:

- a support base 410;
- an upright support member 422 affixed to the base;
- an operator support 420, such as a seat, affixed to the upright support member 422;
- a hand support 430 affixed to the upright support member 422;
- a crank assembly 440 supported directly and/or indirectly by the support base 410 or a support member;
- pedals 450 attached to the crank assembly 440;
- an electric motor 240;
- a rotational cable 442 affixed to the crank assembly 440 and to the motor 240;
- control electronics 246 electrically connected to at least one of the electric motor 240 and controller 130;
- a display screen 492 attached to a display support 492, which is directly and or indirectly attached to the support base 410; and/or
- an aesthetic housing 480, which is optionally attached, hinged, or detachable from the support base 410.

[0130] In stark contrast with a power generation system where a user pedaling a crank and generates power, the system herein described optionally uses an electric motor to provide a resistance against which the person exercising needs to exert force.

**Orientations**

[0131] As with the with linear movement system 200, the orientations of the rotational movement system 400 are optionally configurable in any orientation and/or with alternative body parts, such as with the hands and arms instead of with feet and legs.

**Resistance/Assistance Profiles**

[0132] As described, supra, with respect to the linear movement system 200, traditional rotary systems have a preset resistance, which is either flat or based upon a fixed cam or set of fixed cams. Referring now to FIG. 5, resistance profiles 500 are illustrated, where the resistance is in arbitrary units as a function of rotation angle theta. For traditional rotation systems, the resistance profile is flat 510 as a function of rotation. In stark contrast, the exercise system 100 described herein allows for changes in the resistance as a function of rotation within a single revolution of movement and/or with succes-
sive revolutions of the rotating element. Typically, resistance variation is a result of changes in the electric motor supplied resistance.

[0133] An example of rotation of a bicycle crank illustrates differences between traditional systems and resistance profiles available using the rotational movement system 500. A flat resistance profile versus rotation 510 is typical. However, the physiology of the body allows for maximum exerted forces with the right leg at about 45 degrees of rotation of the crank (zero degrees being the 12 o’clock position with a vertical rotor) and maximum exerted forces by the left leg at about 225 degrees of rotation of the crank. The computer controlled electric motor 240 allows variation of the resistance profile as a function of rotational angle 520. Unlike a cam system or a bicycle equipped with an elliptical crank, the resistance profile is alterable between successive revolutions of the crank via software and/or without a mechanical change.

[0134] Still referring to FIG. 5, more generally the resistance profile 500 of the rotational exercise system 400 is optionally set:

- according to predetermined average physiological human parameters;
- to facilitate therapy of a weak point in a range of motion;
- to accommodate restricted range of motion, such as with a handicap;
- to fit a particular individual’s physiology;
- to fit a particular individual’s preference;
- in a pre-programmed fashion;
- in a modified and/or configurable manner; and/or
- dynamically based on sensed values from the sensor 150; and/or
- through real-time operator 110 input.

[0145] Several optional rotational resistance profiles are possible, including: a step function resistance profile, a changing resistance profile within a rotation and/or between rotations, a range or programs of resistance profiles. Additional profiles include any permutation and/or combination of all or parts of the profiles listed herein for the linear movement system 200 and/or the rotational movement system 400.

Combinatorial Linear and Rotation Systems

[0146] Referring now to FIG. 6, a combinatorial movement system 200 is illustrated. In the illustrated example, a single electric motor 240 is used for control of two or more pieces of exercise equipment, such as:

- an isometric station;
- a linear movement system 200; and
- a rotational movement system 400.

[0150] Generally, the single electric motor 240 optionally provides resistance to 1, 2, 3, 4, 5, or more workout stations of any type.

[0151] Still referring to FIG. 6, an exercise system is figuratively illustrated showing interfaces for each of: (1) a linear movement system 200 and (2) a rotational movement system 200 with a motor 240 and/or motor controlled wheel 462. The combinatorial movement system 600 is illustrative in nature and is used for facilitating disclosure of the system. However, the illustrated combinatorial movement system 600 is only one of many possible forms of the exercise system 100 and is not limiting in scope.

Sensors

[0152] Optionally, various sensors 150 are integrated into and/or are used in conjunction with the exercise system 100.

Operator Input

[0153] A first type of sensor includes input sources to the computer from the operator 110. For example, the hand support 430 of the rotational movement system 400 is optionally configured with one or more hand control 432 buttons, switches, or control elements allowing the operator 110 to adjust resistance and/or speed of the electric motor 240 within a repetition and/or between repetitions. For example, an increase weight button is optionally repeatedly depressed during raising of a weight, which incrementally increases the load applied by the electric motor 240. A similar button is optionally used to decrease the weight. Similarly foot control buttons 452 are optionally used to achieve the same tasks, such as when the hands are tightly gripped on a weightlifting bar.

Instrumentation Sensor

[0154] A second type of sensor 150 delivers information to the computer of the exercise system 100. In a first example, the pedals 450 of the bicycle assembly are optionally equipped with sensors 150 as a means for measuring the force applied by an operator 110 to the pedals. As a second example, the linear motion system 200 and/or rotational motion system 400 optionally contains sensors 150 for measuring load, position, velocity, and/or acceleration of any movable element, such as the pedals 450 or the weightlifting bar 200.

[0155] For example, muscle loading is controlled using the resistance force exerted on the bar by the electric motor. Position, velocity, and acceleration data are provided by an encoder on the motor and are used as feedback in the control system. For additional muscular overload, often more weight is lowered than can be raised. The lowering or eccentric phase of the exercise can be controlled in real-time for eccentric overload. Muscle loading control and data acquisition is optionally performed, for example, in a dataflow programming language where execution is determined by the structure of a graphical block diagram which the programmer connects different function-nodes by drawing wires, such as LabView® or other suitable software.

Radio-Frequency Identification

[0156] A third type of sensor 150 delivers information to the computer of the exercise system 100 from the operator. For example, the operator wears a radio-frequency identification (RFID) tag, such as in a belt, shoe, wallet, cell phone, article of clothing, or an embedded device. The radio frequency identification identifies the operator to the exercise system 100 along with information, such as any of:

- an operator name;
- an operator gender;
- an operator age;
- an operator height;
- an operator weight;
[0162] an operator physical characteristic, such as arm length, leg length, chest size for an exercise like a bench press;
[0163] an operator workout preference;
[0164] an operator workout history; and
[0165] an operator goal.

[0166] The radio-frequency identification tag is of any type, such as active or battery powered, passive, and battery assisted passive. Generally, wireless signal is received by the exercise equipment 100 from a broadcast source, such as from a global positioning system or RFID tag.

Computer

[0167] The motor drive controller 130 is optionally connected to a microprocessor or computer and power electronics that are used to control the electric motor 240. The power electronics are connected to a power supply such as a battery or power outlet. The computer, the electric drive unit, and the sensors 150 optionally communicate with one another to form feedback control loops allowing the profile of the force and/or resistance applied to the operator 110. The computer optionally provides: a user interface, data storage and processing, and/or communication with other computers and/or a network.

[0168] A visual feedback system 492 is also optionally used to provide the user with immediate feedback on velocity tracking ability and/or other exercise related parameters. Velocity tracking is particularly useful for systems designed for patients in rehabilitation settings.

Microgravity

[0169] In yet another embodiment, the exercise system 100 described herein is designed for use in a microgravity environment. Variations include use of lightweight materials, straps for holding an astronaut relative to the exercise system, and an emphasis on foldable and/or collapsible parts.

Compact/Reconfigurable System

[0170] As described in U.S. patent application Ser. No. 12/545,324, which is incorporated herein, the system 100 is optionally configured as a compact strength training system that provides the benefits associated with free weight lifting and/or aerobic training. Optionally, structure of the exercise system 100 is optionally manually or robotically reconfigurable into different positions, such as a folded position for storage. For example, the weightlifting bar 220 folds, the operator support 420 folds, and/or the support base 410 folds or telescopes.

[0171] Although the invention has been described herein with reference to certain preferred embodiments, one skilled in the art will readily appreciate that other applications may be substituted for those set forth herein without departing from the spirit and scope of the present invention. Accordingly, the invention should only be limited by the Claims included below.

1. An exercise apparatus for operation by a user, comprising:
   a rotatable crank; and
   means for varying resistance of rotation of said rotatable crank, wherein said means for varying resistance comprises use of an electric motor.

2. The apparatus of claim 1, wherein said resistance of rotation varies by at least ten percent during a single revolution of said crank.

3. The apparatus of claim 1, said means for varying resistance further comprising:
   a controller, said controller configured to control the resistance of rotation provided by said electric motor.

4. The apparatus of claim 3, wherein said controller comprises use of a computer implemented function relating human physiological strength to angle of rotation of said rotatable crank.

5. The apparatus of claim 3, said means for varying resistance comprising use of data output from a pressure pad, the data used by said controller to control the varying resistance generated by said electric motor.

6. The apparatus of claim 1, wherein said means for varying resistance of rotation further comprises use of an encoder to determine an angular position of said rotatable crank.

7. The apparatus of claim 1, said means for varying resistance further comprising use of an accelerometer sensor configured to measure acceleration associated with rotation of a shaft of said electric motor.

8. The apparatus of claim 1, wherein said electric motor changes level of said resistance of rotation to at least fifteen separate levels during use of a single program in an exercise period of the user.

9. The apparatus of claim 1, said electric motor configured to supply resistance to movement of at least two workout station user interfaces.

10. The apparatus of claim 1, further comprising:
    a linear movement system, wherein said linear movement system comprises:
    a subject interface element;
    a resistance cable comprising:
    a first cable end attached directly or indirectly to said electric motor;
    a second cable end attached to said subject interface; and
    a controller, said controller configured to control movement of said electric motor, movement of said electric motor configured to provide a force transferred by said cable to said subject interface.

11. The apparatus of claim 1, further comprising:
    a user interface;
    a cable linked to said user interface;
    said electric motor configured to supply a resistive force to movement of said cable;
    said controller configured to provide a feedback sensor reading; and
    a controller electrically connected to said motor, said controller configured to use the feedback sensor reading in control of the resistive force to movement of at least one of:
    said rotatable crank; and
    said cable.

12. A method for exercising a user, comprising the steps of:
    providing a rotatable crank; and
    varying resistance of rotation of said rotatable crank using an electric motor.

13. The method of claim 12, further comprising the step of:
    using a controller electrically linked to said electric motor to vary the resistance of rotation.
14. The method of claim 12, further comprising the step of: controlling the resistance at least two user interface stations with said electric motor.

15. The method of claim 14, wherein at least one of said two user interface stations comprises:
   a handle grip; and
   a cable linked to said handle grip, said electric motor configured to supply a resistive force to movement of said handle grip.

16. The method of claim 15, further comprising the steps of:
   generating a feedback signal with a sensor; and
   using the feedback sensor reading in control of the resistive force applied to movement of at least one of:
   said rotatable crank; and
   said cable.

17. An exercise apparatus for operation by a user, comprising:
   a user interface comprising at least one of:
   a rotatable crank; and
   a handgrip; and
   a cable or linkage connected to said user interface;
   an electric motor configured to supply a resistive force to movement of said user interface;
   a sensor configured to provide a feedback sensor reading; and
   a controller electrically connected to said motor, said controller configured to use the feedback sensor reading in control of said motor generating the resistive force.

18. The apparatus of claim 17, said sensor configured to generate said feedback sensor reading in response to interaction by the user.

19. The apparatus of claim 17, said controller configured to automatically adapt the resistive force based upon an observation of a mechanical element, said mechanical element not touched by the user.

20. The apparatus of claim 17, wherein said electric motor comprises an electric servo assist/resist motor.

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