ISOKINETIC EXERCISE PROCESS AND APPARATUS

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10 Sheets-Sheet 5

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Fig. 22

- Parts labeled with numbers and letters
- Diagram of mechanical components
ISOKINETIC EXERCISE PROCESS AND APPARATUS
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ABSTRACT OF THE DISCLOSURE

The process and apparatus for isokinetic muscular exercise provides for exercise movement which are initiated and maintained by active muscular forces continuously provided by a person exercising. The speed of an exercise movement is allowed to accelerate essentially unopposed by resistance forces from zero to a pre-set or predetermined rate of speed, and any magnitude of muscular force tending to accelerate the exercise movement beyond the predetermined rate of speed is counteracted by the system, thereby establishing the predetermined rate of speed as the maximum rate of speed attainable and loading the particular muscles in proportion to the force they can develop at such speed.

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This invention is directed to a process for active resisted exercise and to exemplary apparatus for performing such a process.

Various processes of exercises are well known, and are discussed in "The Principles of Exercise Therapy" by M. D. Gardner et al., G. Bell and Sons, Ltd., London, 1957. In resisted exercise, an external force is applied to the body limbs to oppose the forced muscular contraction. Apparently, over a period of time, as tension is increased within the muscles by the opposing or resisting external force, the muscles develop an increase in their power and hypertrophy.

This external force may be applied either dynamically or statically.

In the static case, the person exercising is customarily opposed by a relatively immovable object. This may be, for example, a wall, or an opposite and equally strong limb. In any event, the muscle does not move after its initial contraction. Such isometric contraction facilitates maximum effort to be exerted by the muscles for a short period of time. However, it is believed that isometric contraction may produce irritation of the joints and warping of the bones, and provides little gain in dynamic strength since it does not enable maximum effort to be exerted through a natural path of movement of a body component.

In the dynamic case, the person exercising is resisted by a relatively yielding force. Such a force can be provided by weights, springs or manual pressure applied by the physiotherapist. A yielding force permits exercise of the muscle over the full range of movement of the muscle. The muscle, however, is not equally powerful throughout its entire range of motion. While the muscle, physiologically, is strongest when fully extended, because of the mechanical advantage of the limbs to which it is attached, the person exercising is generally strongest or has a highest output force in the midrange of movement. Advantageously, the resistive force should vary as the output force of the person exercising. When starting or finishing the movement, a lower opposing force than that required in midcourse is generally advantageous. Such variations in resistive force is not readily obtainable with weights or springs. Such a variation can be approached by the physiotherapist applying manual pressure to oppose the person exercising, but the forces involved are not readily measurable. It is desirable that the resistance be measurable so that the progress of the person exercising can be recorded.

Accordingly it is an object of this invention to provide a process and apparatus for exercising which will oppose the movement of the person exercising the full range of movement of the muscle, and which will afford any desired, adjustable in course, resistive force which the person exercising is capable of overcoming and which will also be in equilibrium with the person's applied force, avoiding recoil or unbalancing effects.

It is another object of this invention to provide an apparatus which will accommodate controlled constant efforts, uncontrolled variable efforts, and maximum efforts.

It is yet another object of this invention to provide an apparatus which will afford a direct read out of the dynamic force applied by the person exercising throughout the course of his movement.

It is still another object of this invention to provide a speed of movement which is constant and thereby predictable and secure to the person exercising, providing safe and favorable exercise conditions for optimal dynamic neuromuscular exercise.

It is even another object of this invention to provide an apparatus which guides the movement of the person exercising, which guided movement may be made concentric to the axis of the joint on which the limb and muscle being exercised operate, and co-planar with such muscle.

These together with other objects and advantages which will become subsequently apparent reside in the details of construction and operation as more fully hereinafter described and claimed, reference being had to the accompanying drawings forming a part hereof, wherein like numerals refer to like parts throughout, and in which:

FIGURE 1 is a perspective view of one embodiment of the invention;
FIGURE 2 is a fragmental sectional view illustrating further structural details of the apparatus of FIGURE 1;
FIGURES 3–6 illustrate schematically different manners of use of the apparatus illustrated in FIGURES 1 and 2;
FIGURE 7 is a fragmental sectional view illustrating further structural details of the apparatus;
FIGURE 8 is a schematic view of the closed loop system incorporating the process of the present invention therein;
FIGURE 9 is a perspective view of another type of apparatus;
FIGURE 10 is a detail sectional view along section line 10—10 of FIGURE 9 illustrating further structural details of this form of the invention;
FIGURE 11 is a detail sectional view taken along section line 11–11 of FIGURE 9 illustrating further structural details of this form of the invention;
FIGURES 12 and 13 illustrate schematically exemplary ways of using this invention;
FIGURE 14 illustrates an hydraulic system usable in the hydraulic embodiments of this invention;
FIGURE 15 is a schematic diagram of a modification of the hydraulic system of FIGURE 14;
FIGURE 16 is a schematic diagram of a mechanical system embodying the principles of this invention; FIGURE 17 is a top view in plan, partially broken away, of a first mechanical embodiment of FIGURE 16; FIGURE 18 is a side view in elevation, partially broken away, of the apparatus of FIGURE 17; FIGURE 19 is an end view in elevation, partially in section of the apparatus of FIGURE 17; FIGURE 20 is a top view in plan, broken away, of a second mechanical embodiment of FIGURE 16; FIGURE 21 is a side view in elevation, partially broken away, of the apparatus of FIGURE 20; FIGURE 22 is an end view in elevation, partially in section, of the apparatus of FIGURE 20; FIGURE 23 is a perspective view of an adjustable support for the mechanical system of FIGURE 16; FIGURE 24 is a sectional view in elevation, taken along plane 24—24 of FIGURE 23; FIGURE 25 is a sectional view in elevation, taken along plane 25—25 of FIGURE 24; FIGURE 26 is a sectional view in plan, taken along plane 26—26 of FIGURE 25; FIGURE 27 is a perspective view of an adjustable support for the adjustable support of FIGURE 23.

Muscle Exercise may be characterized as follows:

(I) Active Exercise wherein the subject exerts the muscular force producing the exercise motion.

(II) Passive Exercise wherein the subject does not exert the muscular force producing the exercise motion.

(A) Concentric Contraction wherein the muscle shortens while the subject is contracting against external resistance.

(B) Eccentric Contraction wherein the muscle lengthens while the subject is contracting against external resistance.

1. Isotonic Contraction or Exercise wherein the external resistance force remains constant during a dynamic contraction, so that the speed of the exercise motion varies in response to the magnitude of the muscular force.

2. Isometric Contraction or Exercise wherein the length of the muscle is held constant during a static contraction, so that the external resistance force varies in response to the magnitude of the muscular force.

3. Isokinetic Contraction or Exercise wherein the speed of the exercise motion is held constant during a dynamic contraction, so that the external resistance force varies in response to the magnitude of the muscular force.

This invention is primarily concerned with Active, Concentric, Isokinetic Exercise.

However, it will be apparent that it has utility in Passive Exercise, in Eccentric Contraction, and in Isometric Exercise.

Exemplary apparatuses for carrying out the process of the present invention have been disclosed in the drawings with the apparatus illustrated in FIGURES 1–7 being designated generally by numeral 12 and including a base or platform 12 having a rigid standard 40 mounted thereon and including a telescopic first section 16 secured in an adjusted position by a fastening bolt or pin 18 inserted through one of a plurality of longitudinally spaced apertures 20. Mounted on the standard 14 is a housing 22 secured in place by an adjustable mounting bracket 24. The upper end of the housing 22 journals a shaft 26 which extends outwardly from the housing and is journaled in a base or platform 28 as the telescopic section 16. Further, the shaft 26 has a sleeve 30 on the end thereof which adjustably receives an elongated arm 32 having a plurality of longitudinally spaced apertures 34 therein for receiving a fastening pin or bolt 36 thus enabling the effective length of the arm 32 to be adjusted. At the outer end of the arm 32, there is provided an adapter sleeve 38 for detachably supporting an elongated handle 40 which extends into overlying parallel relation to the platform or base 12. This enables a person to stand on the base or platform and grasp the elongated handle 40 for operation of the arm 32 to be swung about the axis of the shaft 26. Interiorly of the housing 22, there is provided a lower shaft 42 in parallel relation to the shaft 26. A pulley 44 is keyed to the shaft 26 and a pulley 46 is keyed to the shaft 42 for receiving a flexible belt, cable, or the like. Furthermore, interconnecting the ends of the flexible belt or cable 48 is an elongated rod 50 having a piston 52 formed centrally thereon for movement within a cylinder 54 thus forming a hydraulic pump the details of which will be discussed in conjunction with FIGURE 14. A pressure hose 56 is connected with the pump and is connected with a pressure gauge 58 mounted on the handle 40 for movement therewith so that the pressure on the pressure gauge 58 may be observed.

FIGURE 7 illustrates the structure for supporting the handle 40 on the sleeve adapter 38 which is in the form of split rings 60 or the like for locking the handle 40 in place but enabling rotation thereof in relation to the sleeve 38.

FIGURES 3–6 illustrate different manners of use of the invention whereby the rotational axis of the shaft 26 may be oriented in alignment with articulation joints in the body. FIGURE 3 illustrates the orientation of the axis of the shaft 26 coincidental with the joint at the shoulder. FIGURE 4 illustrates an arrangement in which the axis of the shaft 26 is coincidental with the knee joint and a seat is provided with the feet engaging the handle 40. FIGURE 6 illustrates an arrangement in which the axis of the shaft 26 is aligned with the hip joint.

FIGURES 9–13 illustrates another embodiment of the invention generally designated by numeral 62 which includes an elongated channel-shaped base 64 having a seat cushion 66 mounted on one end thereof and an upright standard 68 pivotally supported from a hinge point in the form of a bolt or the like 70 at the lower end thereof. Stirrups 72 for receiving the feet are positioned on the base 64 alongside of the lower end of the standard 68. Also positioned in the base 64 is a cylinder 74 having a piston movable therein with one end thereof 80 connected to an elongated piston rod 76 rigidly fixed to an elongated rack gear 78 slidable in a channel-shaped guide 80 fixed within the base 64. The upright standard 68 has a pulley 82 journalled at the upper end thereof and a pulley 84 on the pin or shaft 70 with a cable or flexible belt 86 entrained therein in a manner that will assure positive movement of at least the lower pulley 84 when the flexible belt 86 is moved. Such positive movement may be provided by gear teeth being formed on the inner surface of a flexible V-belt 86 for positive engagement with a toothed pulley 84.

Movable mounted on the standard 68 is a slide 88 having connecting means 90 and 92 thereon for connection with the ends of the belt 86, as illustrated in FIGURE 10. The slide 88 includes a laterally extending arm 94 having outwardly extending handles 96 thereon. Disposed between the slide plates which form the slide 88 are three rollers 98 with two of the rollers engaging one side of the standard 68 and the other roller engaging the other side of the standard 68 for vertically guiding the slide 98 movably on the standard 68. The ends of the slide plates forming the slide 88 extend inwardly as at 100 for guiding inner end of the base 64. As the standard 68 is vertically disposed, the slide 88 may be moved longitudinally thereon in a manner illustrated in FIGURE 12 with a corresponding angular movement of the standard 68 if desired whereby the ankle joints are generally aligned with the ankle or shaft 70. Such vertical reciprocation of the slide 88 will cause reciprocation of the rack gear 78 due to a pinion gear 102 secured to the shaft 70 and which is also secured to the pulley 84. Thus the pinion gear 102 rotates in response to vertical reciprocation of the slide 88. As illustrated in FIGURE
13, the standard 68 may be pivoted downwardly into the base 64 and the seat 56 may then be used along with the handles 96 which become footrests. The slide 88 may be horizontally reciprocated which will cause the same reciprocation of the rack gear 78. As illustrated, a pressure gauge 128 is provided for observation by the user of the device to enable the hydraulic pressure derived from the pump to be observed.

In FIGURE 14, the hydraulic system is illustrated including a piston 106 movable in a cylinder 108 having a conduit 110 extending from one end thereof and a conduit 112 extending from the other end thereof. Extending inwardly from the conduit 112 is a conduit 114 having a check valve 116 therein and extending inwardly from the conduit 110 is a conduit 118 having a check valve 120 incorporated therein. A fitting 122 interconnects the check valves and is provided with an outlet conduit 124 having a fitting 126 connected with a pressure gauge 128.

A gate valve 130 is also provided in the conduit 124 and a constant flow valve 132 is provided in the conduit 124 and the discharge of the constant flow valve 132 extends into a fitting 134 having a check valve 136 at one end thereof and a check valve 138 at the other end thereof which in turn are communicated with the conduits 112 and 110 respectively, so that flow from one side of the cylinder 108 to the other will be restricted. The constant flow valve 132 so that the rate of movement of the piston 106 in relation to the cylinder will be constant. The pressure gauge 128 is calibrated to indicate pounds of pressure divided by the mechanical advantage of the linkage system involved to provide a true indication of the force exerted by the user at the point of application of the force.

It will be noted that the hydraulic system of FIGURE 14 permits only constant velocity movement of the piston 106 in either direction. Under certain circumstances it is desirable to permit other movements. For example, it may be desired to permit the person exercising to push at a constant velocity in one direction and to pull back rapidly without constraint in the other direction. Alternatively, it may be desired to permit the person exercising to pull at a constant velocity in one direction and to push rapidly without constraint in the other direction. These circumstances both directions obtained when the person is desired to exercise one set of muscles but not another opposing set connected to the same limb. Under circumstances where it is desired to permit the person exercising to move his limb without exercising his muscles, as to preclude cartilage binding a joint, it is desirable to permit free movement in the direction only, and then only when the inner element is already being rotated in that direction at the same velocity that the outer element is rotating. The inner element of the clutch 256 is fixed to a shaft 258 which is fixed to a gear 260. A worm gear 262 is meshed with and driven counterclockwise by the worm 250 and is fixed to the outer element of an overrunning clutch 263. The inner element of the clutch 263 is fixed to a shaft 264 which is fixed to a gear 266. The gears 260 and 266 are each meshed with a gear 268 which is fixed to a shaft 270. A cog wheel 272 is fixed to the shaft 270 and is adapted to be driven either clockwise or counterclockwise by the person exercising. The worm 270 is equivalent to the shaft 42 shown in FIGURE 2, and the pulley 272 is equivalent to the cog wheel 46 therein. The clutch 256 is adapted to transmit torque only in the counterclockwise direction. The clutch 263 is adapted to transmit torque only in the clockwise direction.

Thus, when the person exercising rotates the shaft 270, neither of the clutches 256 or 263 is engaged to transmit torque, and the worm 250 is rotated by its electric motor 252 without loading. When the person exercising rotates the shaft 270 clockwise, the shaft 258 is rotated counterclockwise, at the threshold speed, and the clutch 256 engages to transmit force to the worm 250. The clutch 254, the clutch 256, the gear 260 and the gear 268 to the shaft 270. Regardless of...
how much torque the person exercising applies to the shaft 270, the worm 250 will rotate at this constant speed, in effect, resisting an aiding load. Similarly, when the person exercising rotates the shaft 270 counterclockwise, the shaft 264 is rotated clockwise at the threshold speed, and the clutch 263 engages to couple the worm 250 through the worm gear 262, the clutch 263, the shaft 264, the gear 266 and the gear 268 to the shaft 270.

The system, once a clutch has been engaged, is not capable of being accelerated by the person exercising, due to the unidirectional characteristic of the motor and the worm drive. Any applied force over the threshold to engage a clutch will be opposed by a reaction force from the mechanical system, while the system relatively slowly yields, apparently under the applied force. When the applied force ceases, as when the person exercising comes to the end of his movement, the system stops moving.

Thus the system applies a kinetic resistance to the action of the person exercising, which is delicately responsive to the force which he applies, and is always slightly less than the force which he applies, from instant to instant.

Additional features may be incorporated into the mechanical system. The motor is energized by a source 274. A switch 276 in series with the motor, by deenergizing the motor, provides an “isometric hold.” A speed controller, for example, comprises an autotransformer, a potentiometer and a silicon control rectifier arrangement, is provided to adjustably vary the speed of the motor 252. A force sensing means, here shown as a pressure sensitive resistance 280, and a current source 282, are coupled to the output of a relay 284. When at least a threshold force has been applied to the resistance 280, the relay 284 closes, energizing the motor 252. A pair of magnetic clutches 286 and 288 are respectively interposed in series with the shafts 258 and 264. The maximum torque which can be transmitted by the clutch 286 is adjusted automatically by a rheostat 290 in series with a source 292. The maximum torque which can be transmitted by the clutch 288 is adjustable controlled by a rheostat 294 which is in series with the clutch 288. These clutches 286 and 288 begin to slip at the maximum torque, and any force over such a maximum applied by the person exercising will be dissipated in acceleration.

Turning now to FIGURES 17, 18 and 19, it will be seen that the embodiment of the control mechanism schematically shown in FIGURE 17 comprises a left wall plate 300 and a right wall plate 302. An electric motor 304 has an output shaft 306 which is connected to a reduction gear assembly 308. The reduction gear assembly has a housing which is mounted to the left wall plate 300 by suitable machine screws 308, and has an output shaft 310. A shaft 312 having a worm 314 fixed thereon by a key 316 is fixed to the shaft 310 by a coupling 318. The shaft 312 is journaled in two bearings 320, 322 respectively mounted in two brackets 324, 326, which brackets are respectively mounted to the right wall plate 302. A thrust bearing 328 is mounted on the shaft 312 and has one race 330 which abuts against a shoulder 332 on the shaft. The other race 334 clearly the shaft. Two counter cam rods 336, 338 are mounted between the left and right wall plates 300 and 302. Each rod has a right pivot portion 340 disposed in a hole 342 in the right plate 302 and a left pivot portion 344 disposed in a hole 346 in the left plate 300. Each rod also has a large diameter, eccentric or cam portion 348 and a smaller diameter, eccentric portion 350, which is coxial with the portion 348. A spring plate 352 has an aperture 354 through which the shaft 312 passes with clearance. The plate 352 abuts the race 336 of the thrust bearing 328, and the eccentric or cam portions 348 of the two rods 336, 338. The angular rotational position of the two rods 336, 338 determines the axial load on the shaft 312.

The worm 314 is meshed with two worm gears 356 and 358. The worm gear 356 is fixed to the shaft 364 by a key 362, and the worm gear 358 is fixed to the shaft 364 by a similar key, not shown. The shaft 360 is journaled at one end in a bearing 366 which is fitted into an aperture 368 in the frame plate 302, and is journaled at its other end in a bearing 370 which is fitted into an aperture 372 in the frame plate 300. A clockwise torque transmitting roller clutch 374 is fitted on the shaft 360 and a spur gear 375 is fixed on the clutch 374. The shaft is longitudinally located by two thrust washers 376 and 378. A shaft 364 is similarly journaled through an aperture 362 in the frame plate 312, and an aperture 354 in the frame plate 300, and has two bearings 386, 388. Two thrust washers 390, 392, a counterclockwise torque transmitting roller clutch 394, and a spur gear 396. Suitable clutches are sold by The Torrington Company, Torrington, Conn., as Drawn Cup Roller Clutch-and-bearing assemblies, catalogue RC-3.

A shaft 398 is journaled through a bearing 400 fitted in an aperture 402 in the plate 300. A gear 404 is fixed to the shaft 398 and is meshed with the gears 375 and 396. A sleeve 406 having an annular flange 408 is mounted concentrically with the shaft 398, and is secured to the plate 310 by machine screws 410. A depth gage 412 has a housing 414 mounted to the plate 362, and a spring loaded plunger 416 which is in end abutment with the shaft 312. The plunger 416 is coupled, via a rack and a gear, to an indicating pointer 418. A gage 412 to indicate axial displacement of the shaft 312.

In use, the electric motor 304 rotates the worm 314, which is normally decoupled from the shaft 398 by the two clutches 374 and 394. When the person exercising applies a force adequate to rotate either the gear 375 at the same speed as the shaft 360 or the gear 396 at the same speed as the shaft 364, the respective clutch 374 or 394 is engaged, and the worm 314 opposes any additional force applied thereto. The greater the force applied by the person exercising, the greater the reaction force opposed thereto. Any additional force, however, tends to move the shaft 312 axially against the spring plate 352. The axial displacement of the shaft is responsive to the additional force applied. The indication provided by the gage 414 is thus responsive to the additional force applied. Since the threshold force is a constant, the gage 414 is also responsive to the force applied by the person exercising. The spring plate 352 may be adjusted by rotating the cam rod 336 and 338.

Another mechanical embodiment is shown in FIGURES 20 and 22. Here, a left wall plate 418 and a right wall plate 420 are held together by a connecting link 422 fixed to a spacer block 422 and machine screws 424. An electrical motor 426 has an output shaft coupled to a speed reducer 428 having an output shaft 430 and a mounting bracket 432 fixed to the plate 420 by machine screws 434. A shaft 436 is journaled through bearing blocks 438 and 440, having roller bearings 442 and 444, respectively, and both mounted to the plate 420 by machine screws 446 and 448, respectively. One end of the shaft 436 is fixed to the shaft 430 by a coupling 450. A worm 452 is fixed to the shaft 436 by a key 454. The worm 452 is rotated counterclockwise by the motor 426. A shaft 456 is journaled between the plates 418 and 420 by means of two bearings 458 and 460 respectively fitted into apertures 462 and 464 in the plates respectively, and two thrust bearings 466 and 468. A worm gear 470 is fitted to the shaft 456 for rotation therewith by suitable means, such as a pin, not shown. A clockwise torque transmitting roller clutch 472 is disposed on the shaft 456, and a gear 474 is fitted to the clutch 472. A similar shaft 476 is mounted in journals 478 and 480 between plates 418 and 420 and thrust bearings 486 and 488. A worm gear 490, a counterclockwise torque transmitting roller clutch 492, and a gear 494 are fixed to shaft 476. A shaft 496 is disposed through a journal 498, fitted through an aperture 500 in the plate 418. A gear 501 is fixed to the shaft 496, as by a key, not shown, and is
meshed with both of the gears 474 and 494. The electrical motor rotates the worm 452 counterclockwise, to rotate the worm gear 470 clockwise and the worm gear 490 counterclockwise. The worm gears, however, are unable to rotate the worm. A sleeve 502 having an annular flange 504 is fixed to the plate 418, coaxially to the shaft 410, by a plurality of machine screws 506.

A T fitting 508, a lower square section, is fixed to the distal end of the shaft 496. An arm, of hollow square section, 510 is removably fixed within the T. An arm 512, of hollow section, is telescopically fitted into the arm 510, and is adjustably located by a plurality of holes and a pin 514. A cross-arm 516 is journaled to the distal end of the arm 512. Thus, the distance between the cross-arm 516 and the shaft 496 is adjustable.

A plug-cap 518 is fixed over and into the distal end of the sleeve 502. A bearing 520 is fixed into a central aperture 522 in the plug 518, and passes the shaft 496 therethrough. An annular disc 526 is frictionally mounted on the bearing 520. The face of the disc is graduated in degrees, as from 0° to −180° and +180°. A pointer 526 is fixed to the shaft 496, overlying the disc 520. The disc may be rotated to position the 0° graduation under the pointer, and the pointer will then indicate the extent of the rotation of the shaft 496 with respect to the sleeve 502. Secondary maximum excursion indicators, not shown, may be positioned by the pointer if desired.

In use, the shaft 496 is swung by the person exercising. When adequate force is applied, whereby one of the clutches 472 and 492 is rotated at the same speed as the respective shaft 456 or 476, the clutch engages; the worm 452 then resists any additional force applied while rotating. Any additional force tends to displace the worm 452 and its shaft 436 to the right, as seen in FIG. 21.

A cylinder cap 528 is threaded into an aperture 530 in the plate 560 and fastened to the tube 568 by two nuts 532 and 534. The cylinder cap 528 has a bore 536 which is threaded at one end to receive a pressure gage 538, and is threaded at the other end to receive a cylinder 540. A piston 542 having an O-ring 544 is slidable disposed in the cylinder 540. A sensing cell 546, such as a pressure sensitive resistor, is also disposed in part in the cylinder 540.

An adapter shaft 548 is fixed at one end to the end of the shaft 436 which carries the worm 452. The distal end of the adapter shaft 548 has one race of a thrust bearing 550 fixed thereto, the other race bearing against the outer surface of the adapter shaft 548. The bore 536 is filled with a suitable fluid for operating the pressure gage 538.

When the worm 452 and its shaft 436 are displaced axially by the additional force applied by the person exercising, this assembly is shifted axially to the right, as seen in FIG. 21; the thrust bearing 550 loads the sensing cell 546 and the pressure gage 538 in response to the additional force. The indicator of the pressure gage 538 may be visible to the person exercising and his physiotherapist, if any.

The sensing cell 546 may be energized by a remote source of current, or may be self energized by batteries, not shown, clipped into a support bracket 552. The output of the cell may be taken to a transducer for the plotting of force vs. time or force vs. angular movement curves. The same sensing cell may be utilized as was the pressure sensitive resistance 280 to control the threshold force required to start the electric motor 426 rotating.

A support assembly 654 is shown in FIGS. 23 through 25 which is adapted to support the device of FIGURE 22. The assembly comprises a bore plate 556, a base block 558 fixed to the plate by a machine screw 560. An upstanding outer tube 562 is fixed to the block by machine screws 564. An upstanding inner square section tube 566 is fixed to the block 558 by a nut 564 and by welding. An additional outer tube 568 is disposed inside of and in sliding telescopic relation to the tube 562. An additional inner square section tube 570 is disposed out-
Thus, various apparatuses may be provided for accomplishing one of the essential goals of the invention, that is, providing a full range of specific natural movement for coordinated motor learning and full body mechanics conditioning through various engineered apparatuses incorporating a force compensating constant velocity machine having various modifications to provide a suitable base and linkage which enables many new and needed exercises to be practiced. This is especially significant in the field of physical therapy for enabling various muscles previously incapable of being easily exercised to be stimulated in an effective and efficient manner.

As illustrated by the schematic diagram in FIGURE 8, the external control of the force receiving member, e.g., handles 40 and 96 of FIGS. 1 and 9, respectively, provides a positive feedback to the central nervous system thus enabling application of maximum muscle force over the full range of motion with a minimum of natural inhibitions. The fact that maximum force can be applied to the force receiving member or grip connections of FIG. 8 and inasmuch as the movement is governed by a force compensating constant velocity apparatus or machine, the central nervous system of the user will substantially withhold protective inhibitions thereby enabling the user to exert the full force capable throughout the range of movement of the force receiving member.

The apparatus of the present invention produces a favorable environment in that the user of the apparatus is comfortable and provided with adequate and secure support and also grip connections to enable various exercises to be performed.

In addition to the previously mentioned variations of the engineering aspects of the apparatus disclosed, it is also pointed out that the arrangement illustrated in FIGURE 9 may be varied by incorporating the cylinder 74 vertically in the standard 68 in the portion of a flexible belt 86 opposite from the grip connection or handles 96 being connected to the opposite ends of piston 106 through a block and tackle pulley assembly including a stationary block attached to the standard and a movable block connected to the end of the piston. Accordingly, movement of the handles 96 or grip connections will be transmitted to the piston 106 with a linear movement less than the movement of the handle or grip connections depending upon the reduction ratio of the block and tackle assembly. This will enable different ratios of movement to be incorporated into the device without the limitations that could occur in a rack and pinion assembly. Further, the standard 68 could be rigidly fixed to the base 64 insofar as during its use in an upright position is concerned although it still could be pivoted downwardly to its collapsed position for use in a horizontal position. Thus, rather than the standard 68 pivoting during reciprocation of the handles 96 or grip connections, the grip connections or handle could move in a vertical path and components of the body move laterally in relation to the standard during reciprocation of the handle or grip connections.

The foregoing is considered as illustrative only of the principles of the invention. Further, since numerous modifications and changes will readily occur to those skilled in the art, it is not desired to limit the invention to the exact construction and operation shown and described, and accordingly all suitable modifications and equivalents may be resorted to, falling within the scope of the invention as claimed.

What is claimed is:

1. Apparatus for use in muscular exercise, comprising: a support; control means secured to said support including a motor having an output shaft with a worm fixed thereto, a first clockwise rotating worm gear and a second counter-clockwise worm gear meshed with said worm, a first clockwise torque transmitting overrunning clutch having an input coupled to said first worm gear and a second counter-clockwise torque transmitting overrunning clutch having an input coupled to said second worm gear, a first additional gear coupled to the output of said first clutch and a second additional gear coupled to the output of said second clutch, a third gear meshed with said first and second additional gears; and grip means, for engagement and movement by a person exercising, coupled to said third gear, for alternately rotating said third gear clockwise and counter-clockwise whereby when said third gear is rotated clockwise at a predetermined rate the other of said clutches engages, and when said third gear is rotated counter-clockwise at the predetermined rate the other of said clutches engages, thereby causing said rotating worm to oppose and preclude rotation of said third gear at a rate greater than the predetermined rate.

2. Apparatus for use in muscular exercise, comprising: a support; control means secured to said support including a motor having an output shaft with a worm fixed thereto, a first worm gear rotating in a first direction and a second worm gear rotating in a second direction opposite to said first direction, both meshed with said worm, a first overrunning clutch transmitting torque in a first direction having an input coupled to said first worm gear and a second overrunning clutch transmitting torque in a second direction opposite to said first direction having an input coupled to said second worm gear, a first additional gear coupled to the output of said first additional gear, a second additional gear coupled to the output of said second additional gear; grip means, for engagement and movement by a person exercising, coupled to said third gear, for alternately rotating said third gear in a first and a second direction, whereby when said third gear is rotated in the first direction at a predetermined rate one of said clutches engages, and when said third gear is rotated in the second direction at the predetermined rate the other of said clutches engages, thereby causing said rotating worm to oppose and preclude rotation of said third gear at a rate greater than the predetermined rate.

3. Apparatus for use in muscular exercise, comprising: a support; control means secured to said support including a motor having an output shaft with a worm fixed thereto, a first worm gear rotating in a first direction and a second worm gear rotating in a second direction opposite to said first direction, both meshed with said worm, a first overrunning clutch transmitting torque in a first direction having an input coupled to said first worm gear and a second overrunning clutch transmitting torque in a second direction opposite to said first direction having an input coupled to said second worm gear, a first additional gear coupled to the output of said first additional gear, a second additional gear coupled to the output of said second additional gear, a third gear meshed with said first and second additional gears; grip means, for engagement and movement by a person exercising, coupled to said third gear, for alternately rotating said third gear in a first and a second direction, whereby when said third gear is rotated in the first direction at a predetermined rate one of said clutches engages, and when said third gear is rotated in the second direction at the predetermined rate the other of said clutches engages, thereby causing said rotating worm to oppose and preclude rotation of said third gear at a rate greater than the predetermined rate; means for sensing the force applied to said third gear by the person exercising and coupled to said control means for precluding said motor from turning said worm whenever the force applied is less than predetermined value.

4. Apparatus for use in muscular exercise comprising: a support; control means secured to said support including a motor having an output shaft with a worm fixed thereto, a first worm gear rotating in a first direction and a second worm gear rotating in a second direction opposite to said first direction, both meshed with said worm, a first overrunning clutch transmitting torque in a first direction having an input coupled to said first worm gear and a second overrunning clutch transmitting torque in a second direction opposite to said first direction having an input coupled to said second worm gear.
pled to said second worm gear, a first additional gear coupled to the output of said first clutch and a second additional gear coupled to the output of said second clutch, a third gear meshed with said first and second additional gears, and a means for engagement and movement by a person exercising, coupled to said third gear, for alternately rotating said third gear in a first and a second direction, whereby when said third gear is rotated in the first direction at a predetermined rate one of said clutches engages, and when said third gear is rotated in the second direction at the predetermined rate the other of said clutches engages, thereby causing said worm to rotate and preclude rotation of said third gear at a rate greater than the predetermined rate; and means for sensing the force applied to said third gear by the person exercising and coupled to said control means for precluding an engaged clutch from transmitting force greater than a predetermined value.

5. Apparatus for use in muscular exercise comprising: a support; control means secured to said support including a motor having an output shaft with a worm fixed thereto, a first worm gear rotating in a first direction and a second worm gear rotating in a second direction opposite to said first direction, both meshed with said worm, a first overrunning clutch transmitting torque in a first direction having an input coupled to said first worm gear and a second overrunning clutch transmitting torque in a second direction opposite to said first direction having an input coupled to said second worm gear, a first additional gear coupled to the output of said first clutch and a second additional gear coupled to the output of said second clutch, a third gear meshed with said first and second additional gears; and grip means, for engagement and movement by a person exercising, coupled to said third gear, for alternatively rotating said third gear in a first and a second direction, whereby when said third gear is rotated in the first direction at a predetermined rate one of said clutches engages, and when said third gear is rotated in the second direction at the predetermined rate the other of said clutches engages, thereby causing said rotating worm to oppose and preclude rotation of said third gear may be oriented coaxially with any predetermined axis provided with said control means whereby the axis of said third gear may be oriented coaxially with any predetermined axis.

8. Apparatus for use in muscular exercise comprising: a support; control means secured to said support including a motor having an output shaft with a worm fixed thereto, a first worm gear rotating in a first direction and a second worm gear rotating in a second direction opposite to said first direction, both meshed with said worm, a first overrunning clutch transmitting torque in a first direction having an input coupled to said first worm gear and a second overrunning clutch transmitting torque in a second direction opposite to said first direction having an input coupled to said second worm gear, a first additional gear coupled to the output of said first clutch and a second additional gear coupled to the output of said second clutch, a third gear meshed with said first and second additional gears; grip means, for engagement and movement by a person exercising, coupled to said third gear, for alternatively rotating said third gear in a first and a second direction, whereby when said third gear is rotated in the first direction at a predetermined rate one of said clutches engages, and when said third gear is rotated in the second direction at the predetermined rate the other of said clutches engages, thereby causing said rotating worm to oppose and preclude rotation of said third gear may be oriented coaxially with any predetermined axis provided with said control means whereby the axis of said third gear may be oriented coaxially with any predetermined axis.
tated in the second direction at the predetermined rate the other of said clutches engages, thereby causing said rotating worm to oppose and preclude rotation of said third gear at a rate greater than the predetermined rate; additional control means coupled to said control means for selectively providing one of the following: (1) precluding said third gear from being drivenly connected to said worm when said third gear is being rotated in one direction, (2) precluding said third gear from being drivenly connected to said worm when said gear is being rotated in the other direction, (3) precluding said third gear from being drivenly connected to said worm.

10. Apparatus for use in muscular exercise comprising: a support; control means secured to said support including a motor having an output shaft with a worm fixed thereto, a first worm gear rotating in a first direction and a second worm gear rotating in a second direction opposite to said first direction, both meshed with said worm, a first overrunning clutch transmitting torque in a first direction having an input coupled to said first worm gear and a second overrunning clutch transmitting torque in a second direction opposite to said first direction having an input coupled to said second worm gear, a first additional gear coupled to the output of said first clutch and a second additional gear coupled to the output of said second clutch, a third gear meshed with said first and second additional gears; grip means, for engagement and movement by a person exercising, coupled to said third gear, for alternatively rotating said third gear in a first and a second direction, whereby when said third gear is rotated in the first direction at a predetermined rate of said clutches engages, and when said third gear is rotated in the second direction at the predetermined rate the other of said clutches engages, thereby causing said rotating worm to oppose and preclude rotation of said third gear at a rate greater than the predetermined rate; means for sensing the force applied to said worm from said third gear when said third gear is drivenly connected through one of said clutches to said worm.

11. Apparatus for use in muscular exercise comprising: a support; control means secured to said support including a motor having an output shaft with a worm fixed thereto, a first worm gear rotating in a first direction and a second worm gear rotating in a second direction opposite to said first direction, both meshed with said worm, a first overrunning clutch transmitting torque in a first direction having an input coupled to said first worm gear and a second overrunning clutch transmitting torque in a second direction opposite to said first direction having an input coupled to said second worm gear, a first additional gear coupled to the output of said first clutch and a second additional gear coupled to the output of said second clutch, a third gear meshed with said first and second additional gears; grip means, for engagement and movement by a person exercising, coupled to said third gear, for alternatively rotating said third gear in a first and a second direction, whereby when said third gear is rotated in the first direction at a predetermined rate one of said clutches engages, and when said third gear is rotated in the second direction at the predetermined rate the other of said clutches engages, thereby causing said rotating worm to oppose and preclude rotation of said third gear at a rate greater than the predetermined rate; means for sensing the force applied to said worm from said third gear when said third gear is drivenly connected through one of said clutches to said worm.

12. Apparatus including a supporting surface and an exercise apparatus mounted on said supporting surface, said apparatus comprising: first means for operative engagement and movement by a portion of the person exercising; second means mounting said first means for back and forth movement in opposite directions and between extreme positions within reach of said portion of said person exercising; and third means, becoming operative upon said first means being moved by said person exercising at a predetermined rate of speed in either of said opposite directions, for establishing said predetermined rate of speed as the maximum rate of speed attainable by said first means in the direction of exercise regardless and substantially independent of the magnitude of the muscular exertion by said person exercising on said first means.

13. Apparatus according to claim 12 further including means for measuring said muscular exertion by said exerciser on said first means.

14. Apparatus according to claim 12 wherein said third means includes means for holding said first means substantially immovable regardless of the muscular force exerted on said first means by said exerciser.

15. Apparatus according to claim 12 wherein said first means is a horizontal bar.

16. Apparatus according to claim 12 wherein said first means includes two portions adapted to be gripped by the hands of said exerciser, and said second means includes mechanism mounting said portions of said first means substantially equidistant from said supporting surface.

17. An apparatus for isokinetic muscle exercise of a subject by use of means movable along a path when a muscular force is applied thereto, said apparatus comprising: means movable along a path, movement of said movable means along said path being initiated and maintained by a subject exercising applying a muscular force thereto, the rate of speed of said movable means below a predetermined rate of speed being determined by and continuously controllable by said subject; and means for precluding acceleration of said movable means along said path beyond said predetermined rate of speed by compensating for any magnitude of applied muscular force tending to accelerate said movable means beyond said predetermined rate of speed.

18. Apparatus for use in muscular exercise comprising: a support; grip means for engagement and movement by a person exercising; first means coupling said grip means to said support for movement along a path, said grip means remaining stationary absent movement by said person exercising; and limiting means, inoperative when said grip means is moved by a muscular force applied by said person exercising at less than a predetermined rate of speed, for precluding acceleration of said grip means beyond said predetermined rate of speed regardless of the magnitude of muscular force applied to said grip means by said person exercising.

19. Apparatus according to claim 18 wherein said first means includes additional means for pivotally coupling said grip means to said support means for movement along a circular path.

20. Apparatus according to claim 18 wherein said first means includes additional means for coupling said grip means to said support means for movement in opposite directions along said path.

21. Apparatus for use in muscular exercise comprising: a support; grip means for engagement and movement by a person exercising; first means coupling said grip means to said support for movement in opposite directions along a given path, said grip means remaining stationary absent movement by said person exercising; and limiting means, inoperative when said grip means is moved by a muscular force exerted by said person exercising at less than a predetermined rate of speed, for precluding acceleration of said grip means beyond said predetermined rate of speed in at least one of said opposite directions so as to establish said predetermined rate of speed as the maximum rate of
speed attainable regardless of the magnitude of muscular force applied to said grip means by said person exercising.

22. Apparatus for use in muscular exercise comprising:

- a support;
- grip means for engagement and movement by a person exercising;

first means coupling said grip means to said support for movement along a predetermined path, said grip means remaining stationary absent movement by said person exercising;

second means becoming operative upon said grip means being moved at a predetermined rate of speed along said path by a muscular force applied by said person exercising for precluding movement of said grip means along said path at a speed greater than said predetermined rate of speed regardless of the magnitude of muscular force applied by said person exercising; and

third means for sensing the magnitude of said muscular force applied by said person exercising and for precluding movement of said grip means along said path when said muscular force is less than a predetermined magnitude.

23. Apparatus for use in muscular exercise comprising:

- a support;
- grip means for engagement and movement by a person exercising;

first means coupling said grip means to said support for movement along a predetermined path, said grip means remaining stationary absent movement by said person exercising;

second means becoming operative upon said grip means being moved at a predetermined rate of speed along said path by a muscular force applied by said person exercising for precluding movement of said grip means along said path at a speed greater than said predetermined rate of speed regardless of the magnitude of muscular force applied; and

third means for sensing the magnitude of said muscular force being applied to said grip means and for overriding said second means to permit movement of said grip means along said path at a speed greater than said predetermined rate of speed when said applied muscular force exceeds a predetermined magnitude.

24. An apparatus for use in muscular exercise comprising:

- a support;
- grip means for engagement and movement by a person exercising, said grip means remaining stationary absent movement by said person exercising;

first means coupling said grip means to said support for movement along a given path; 

second means becoming operative upon said grip means being moved by said person exercising at a predetermined speed along said path for precluding movement of said grip means at a rate of speed greater than said predetermined rate of speed so as to establish said predetermined rate of speed as the maximum rate of speed attainable regardless of the magnitude of muscular force being applied, said second means being further operative to allow movement of said grip means at various rates of speed less than said predetermined rate of speed which are continuously determined by said person exercising.

25. Apparatus for isokinetic exercise of a subject comprising:

- use of means movable along a path when a muscular force is applied thereto, said process comprising the steps of:

engaging with a portion of the subject a movable means which is put in motion by a muscular force applied thereto by said subject;

moving said movable means by the engaged portion of said subject along a path, said movable means being moved along said path essentially unopposed by resistance forces at various rates of speed below a predetermined rate of speed which are continuously determined by and under the control of said subject; and

counteracting any magnitude of applied muscular force tending to accelerate said movable means beyond said predetermined rate of speed thereby establishing said predetermined rate of speed as the maximum rate of speed attainable regardless of the magnitude of muscular force applied by said subject.

26. The process according to claim 25 including the further steps of applying said movable force to said movable means alternately in each of two opposite directions for moving said movable means along said path in said opposite directions; and

counteracting any magnitude of applied muscular force in at least one of said opposite directions.

27. The process according to claim 25 including the further step of moving said movable means in a plane which is perpendicular to the axis of rotation of the limb structure of said subject being exercised.

28. A process of isokinetic muscle exercise of a subject by use of means movable along a path when a muscular force is applied thereto, said process comprising the steps of:

- initiating and maintaining movement of a movable means in opposite directions along a given path by a subject exercising applying a muscular force thereto, the rate of speed of said movable means below a predetermined rate of speed being determined by and continuously controllable by said subject; and

- precluding acceleration of said movable means along said path beyond said predetermined rate of speed by compensating for any magnitude of applied muscular force tending to accelerate said movable means beyond said predetermined rate of speed.

29. The process according to claim 28 further including the step of having said subject perform a concentric muscle contraction for applying said muscular force to said movable means.

30. Apparatus for isokinetic exercise of a subject comprising:

- means movable along a given path when said subject applies a muscular force to said movable means;

and

- means coupled to said movable means for controlling the movement of said movable means along said path in response to said muscular force applied by said subject, said controlling means including means for allowing said movable means to be moved along said path essentially unopposed by resistance forces at various rates of speed continuously determined by and under the control of said subject below a predetermined rate of speed and for counteracting any magnitude of muscular force applied by said subject tending to accelerate said movable means beyond said predetermined rate of speed so as to establish said predetermined rate of speed as the maximum rate of speed attainable regardless of the magnitude of said muscular force being applied by said subject.

31. Apparatus according to claim 30 further including guide means for constraining said movable means to movement in a plane, and means for adjusting said guide means to dispose said plane at any three dimensional angles.

32. Apparatus according to claim 30 further including means for continuously measuring and displaying said muscular force being applied by said subject.

33. Apparatus according to claim 30 wherein said controlling means includes:  a hydraulic cylinder; a piston operable in said cylinder; one of this group consisting of said cylinder and said piston being coupled to said movable means for movement thereby, the other of said group being fixed; a reservoir of hydraulic fluid; and a constant flow rate valve in a hydraulic circuit between said reser-
voir and said cylinder for controlling the flow of fluid between said reservoir and said cylinder.

34. Apparatus according to claim 33 further including a pressure gage coupled to said hydraulic circuit between said cylinder and said valve.

35. Apparatus according to claim 33 wherein said hydraulic circuit is a bridge network coupling said constant flow rate valve between said reservoir and said cylinder whereby said valve is effective in both the compression stroke and the expansion stroke of said piston.

36. Apparatus according to claim 33 further including guide means for constraining said movable means to movement in a plane, and means for adjusting said guide means to dispose said plane at any three dimensional angles.

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