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TWM540670

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Other: **WPI, EPODOC**

(54) Title of the Invention: **Apparatus for exercise and/or for fitness assessment**
Abstract Title: **Fitness testing or exercise apparatus for the double-float transformation phase**

(57) An apparatus for supporting a forwardly facing user in a posture in which one leg trails 22 and the other leg leads 24 comprising a rearwardly facing trailing leg pad 26 arranged to engage a front part of a user's leg at or above the knee, a forwardly facing leading leg pad 30 to engage a rear part of a user's leading leg at or below the kneeing and an upwardly facing trailing leg support 28 extending rearward of the trailing leg pad to support the trailing leg below the knee and maintain it in a state of flexion. The device may have force measurement sensors. A leading foot support 32 have reciprocal movement in fore and aft directions and the leading leg reaction pad may be pivotally mounted. A handle for a user's leading arm may be provided and the reaction pads may be adjustable. A stack of weights may provide a resistance force. Also disclosed is a system with a loading mechanism to exert force on the trailing leg reaction pad. The device is designed for testing or exercise during the double-float transformation during a running stride.

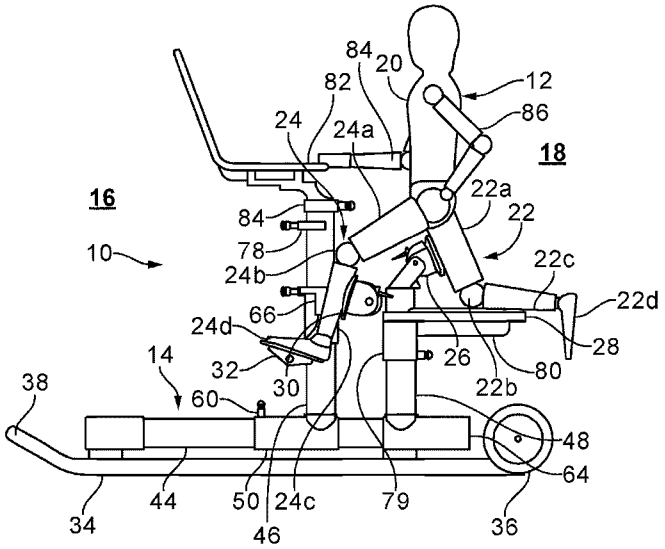

FIG. 1A

GB 2626168 A

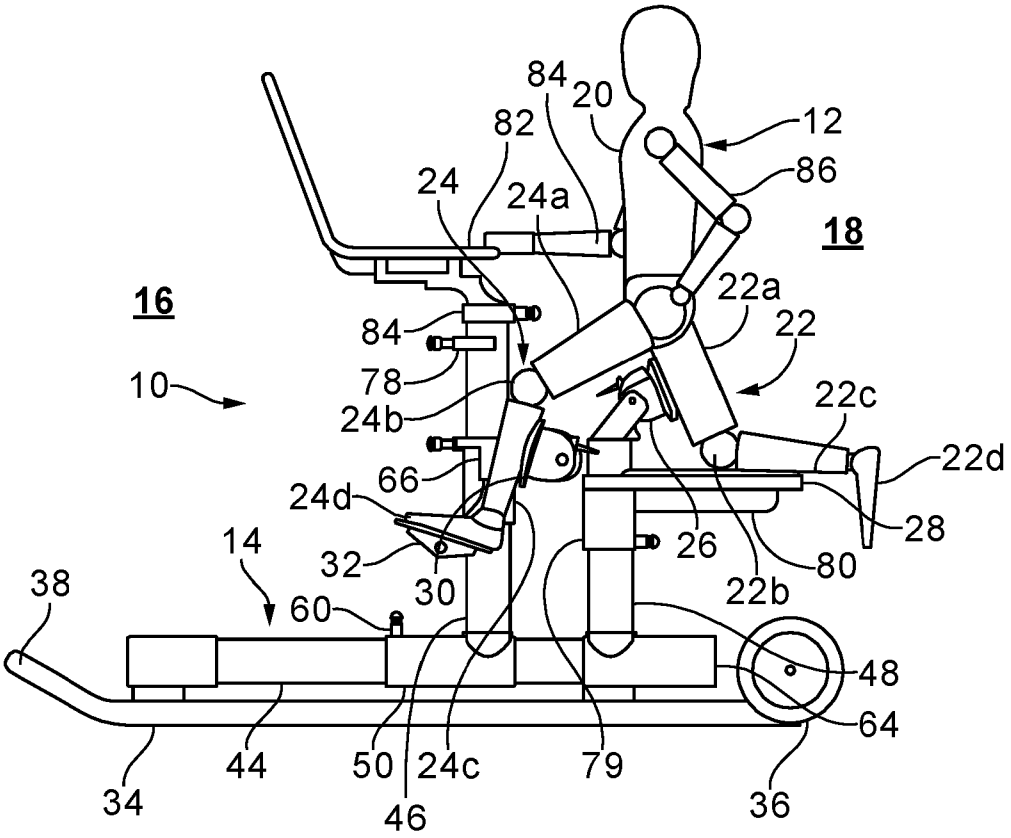
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FIG. 1A

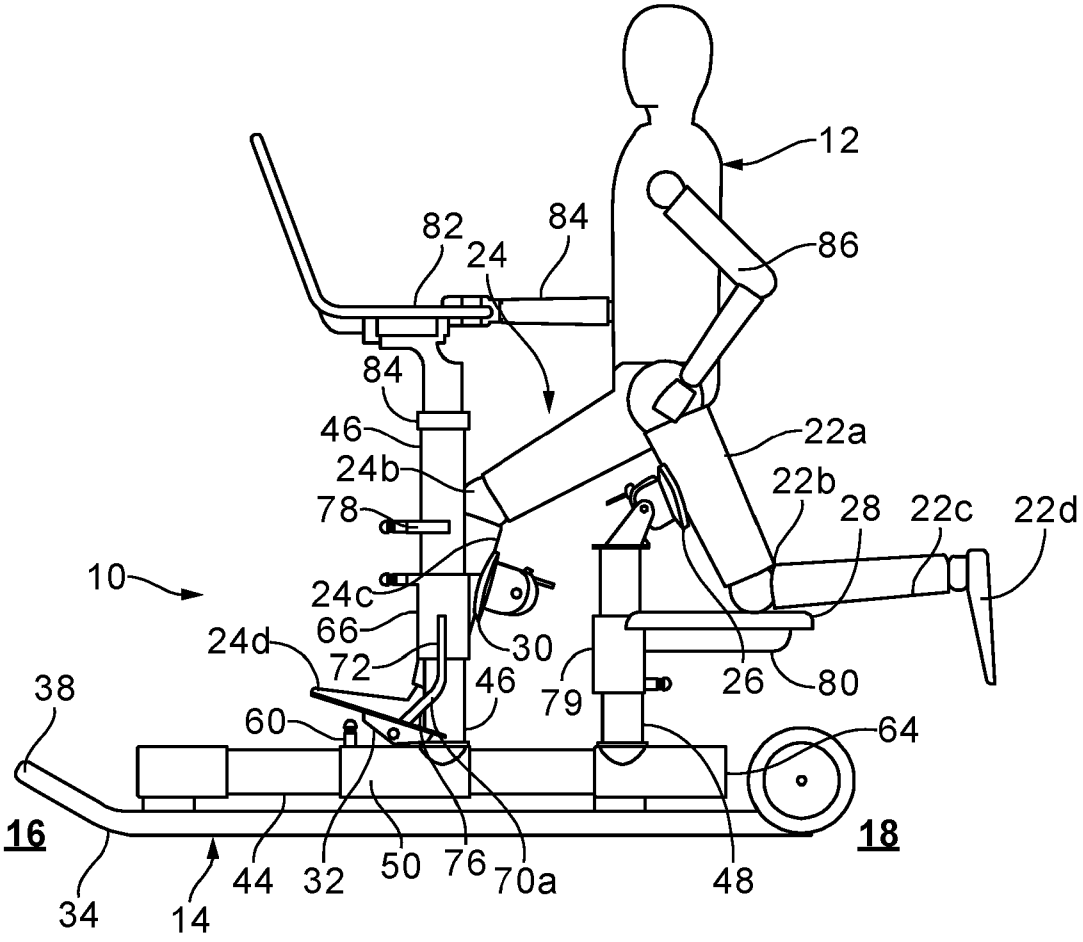
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FIG. 1B

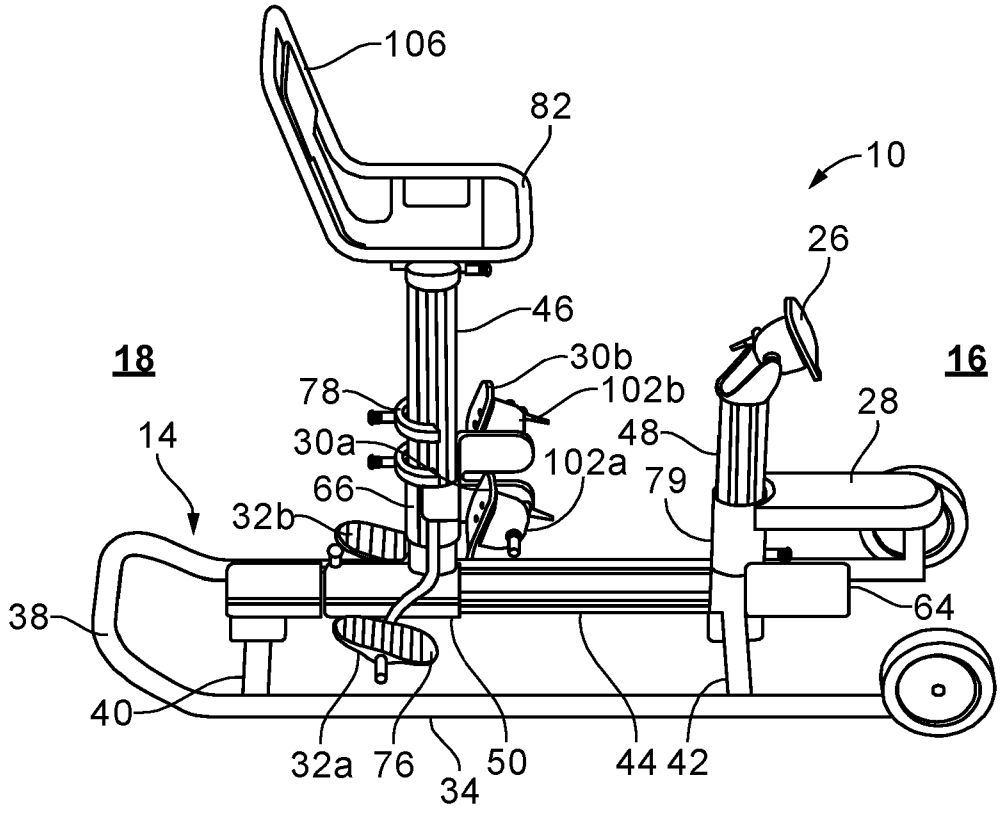
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FIG. 2

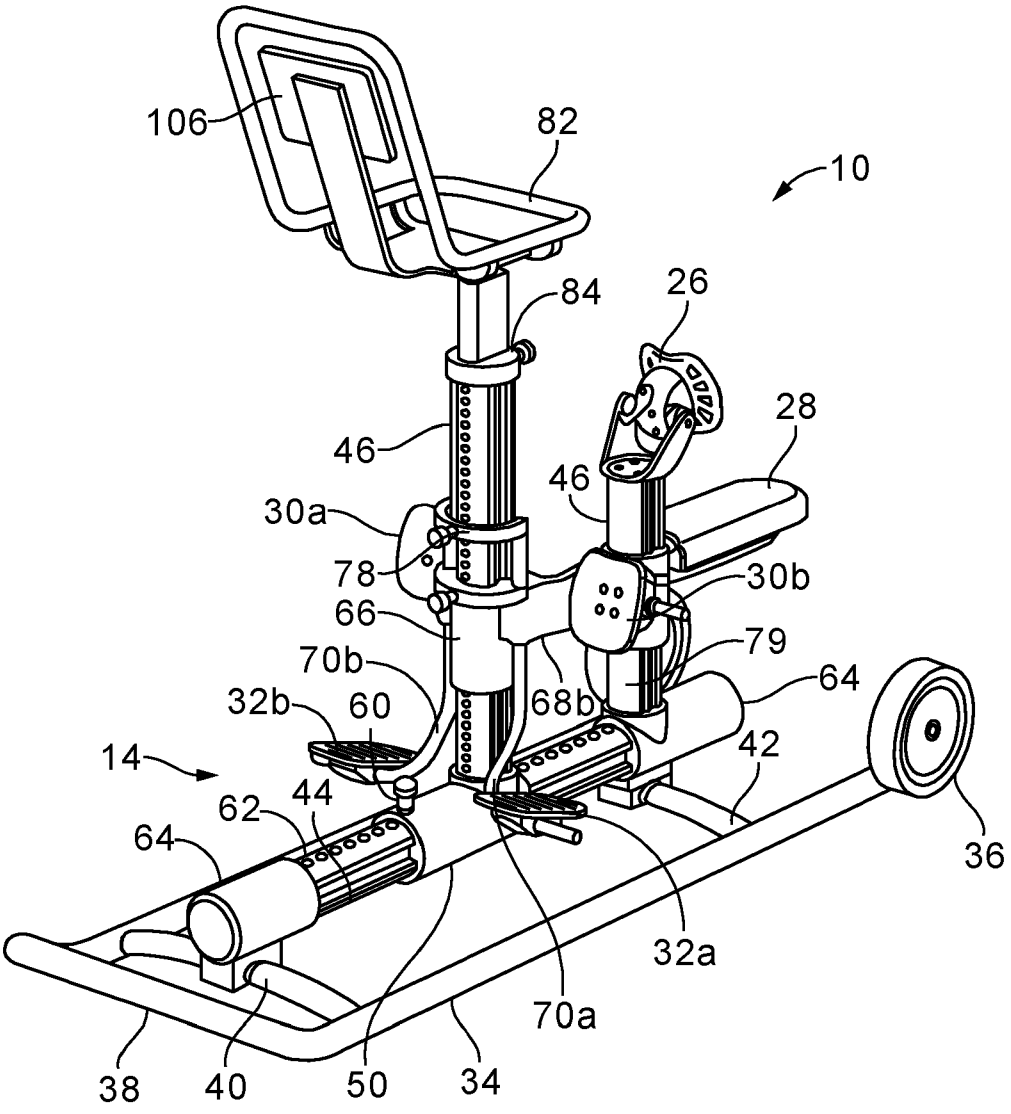
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FIG. 3

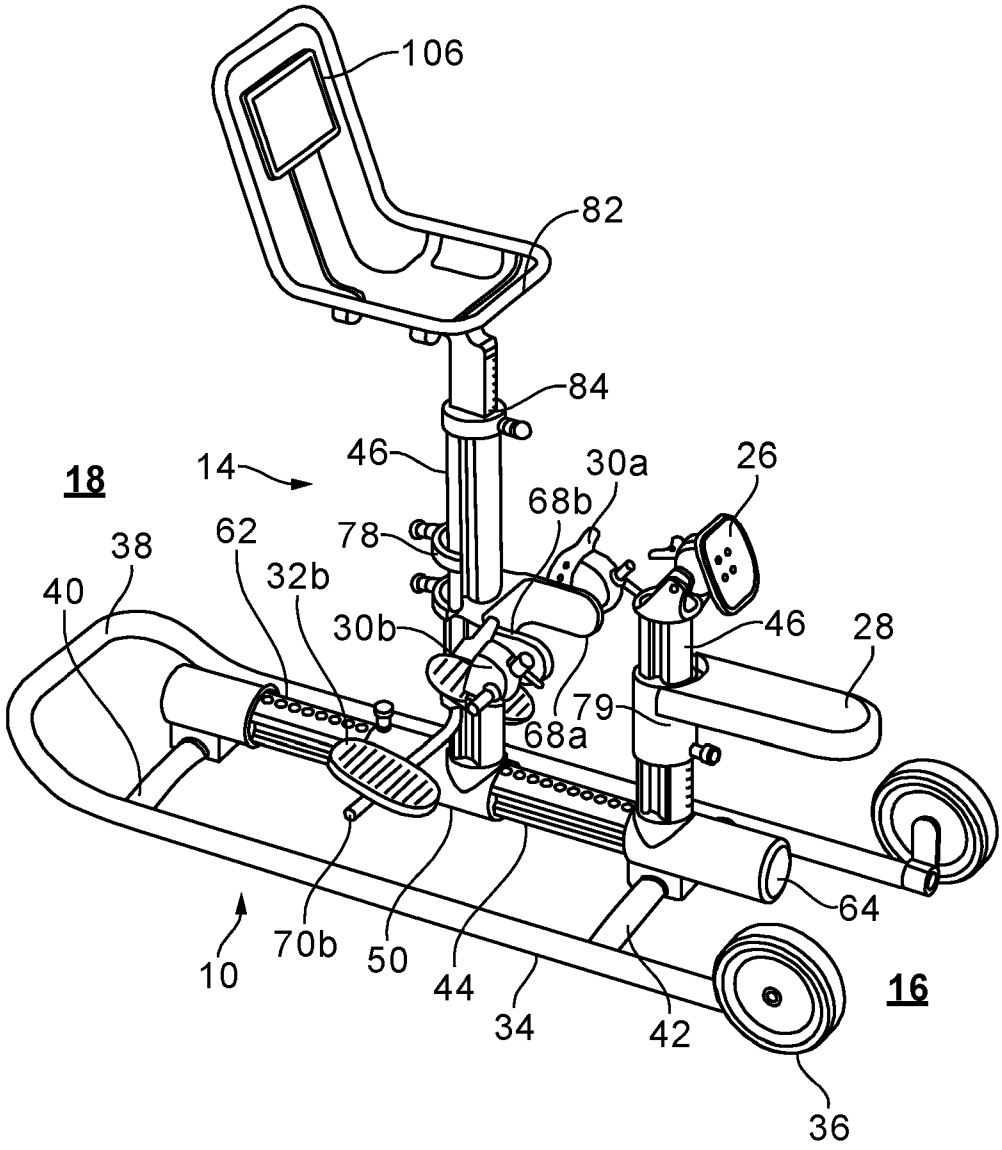
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FIG. 4

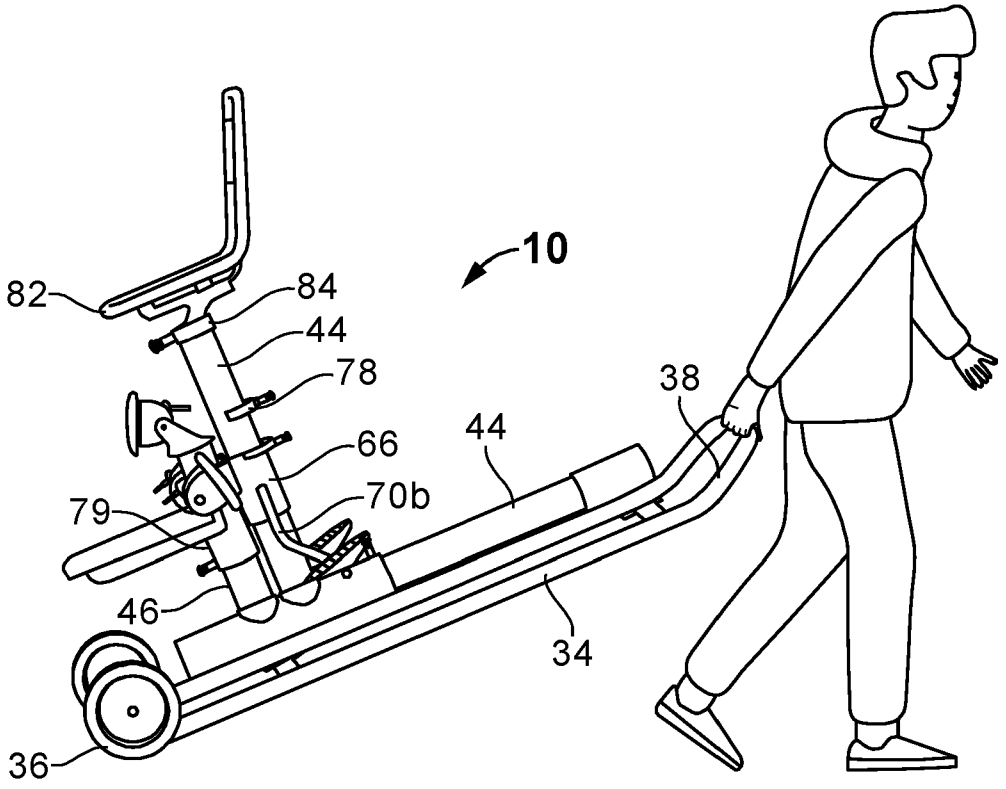

FIG. 5

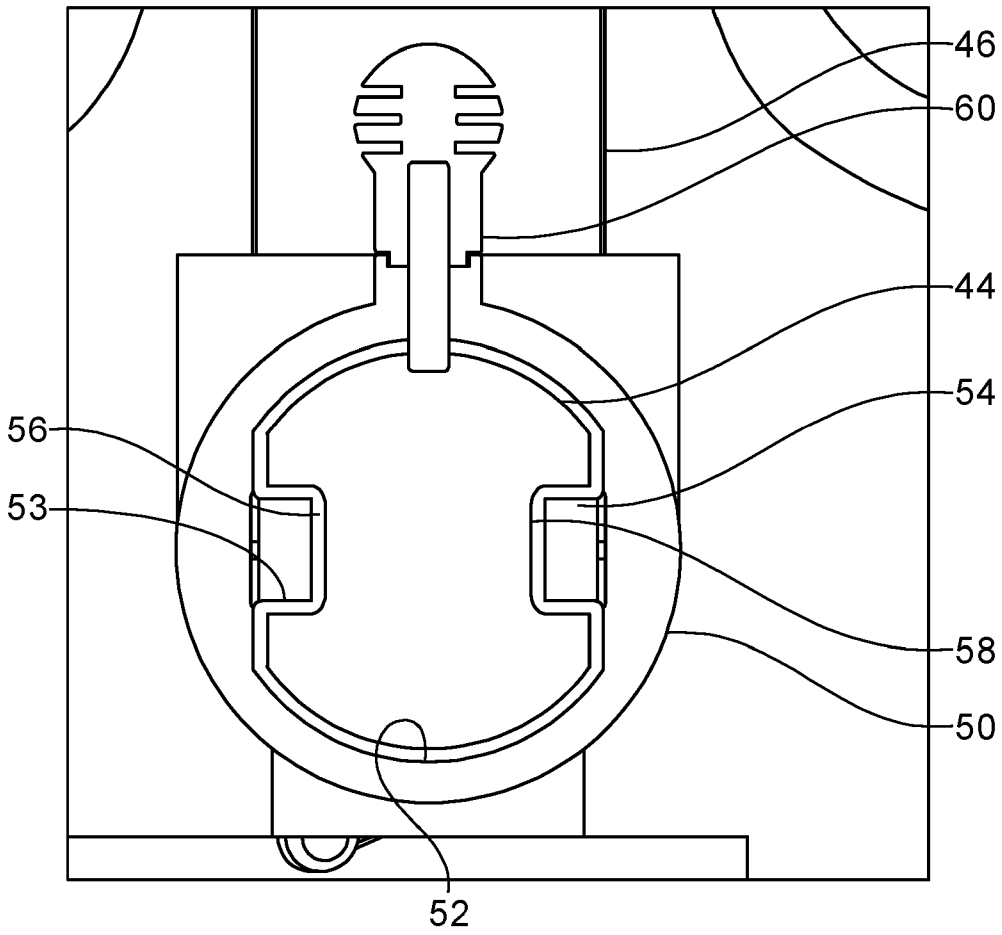

FIG. 6

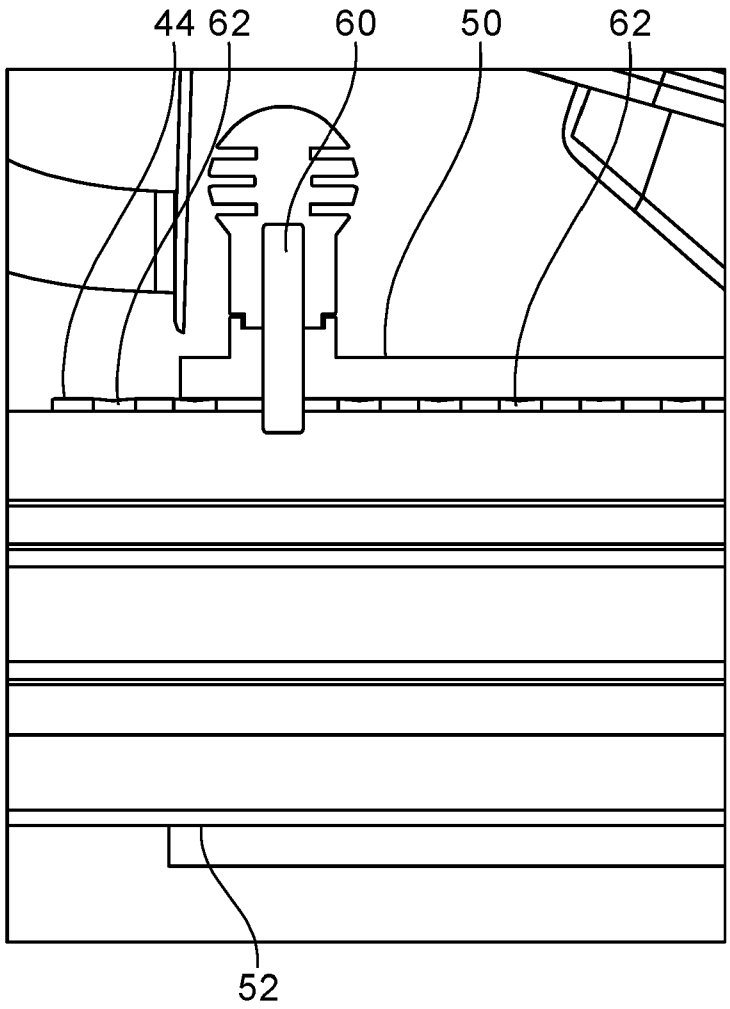

FIG. 7

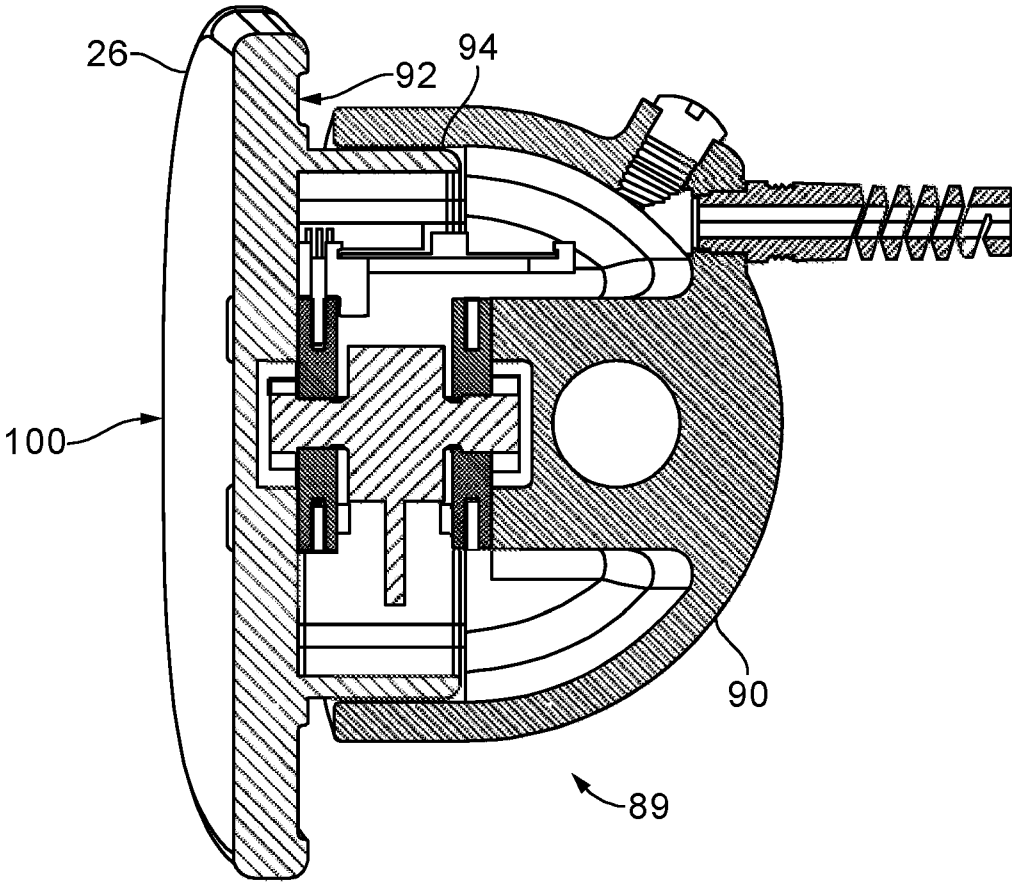

FIG. 8

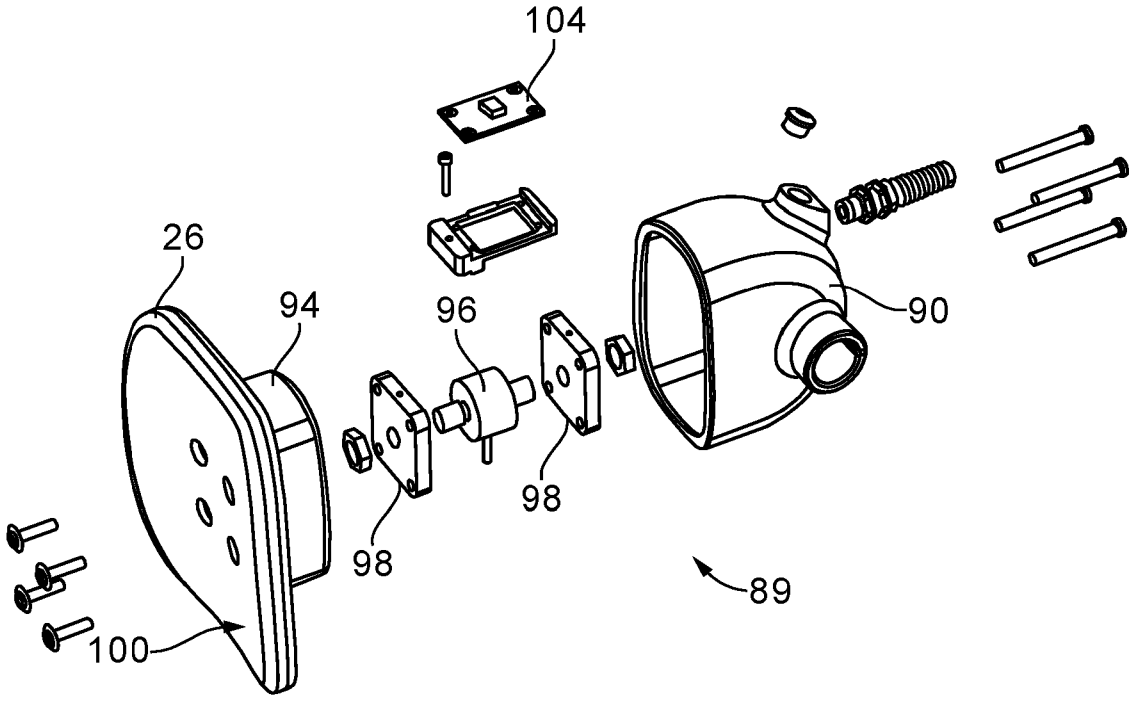

FIG. 9

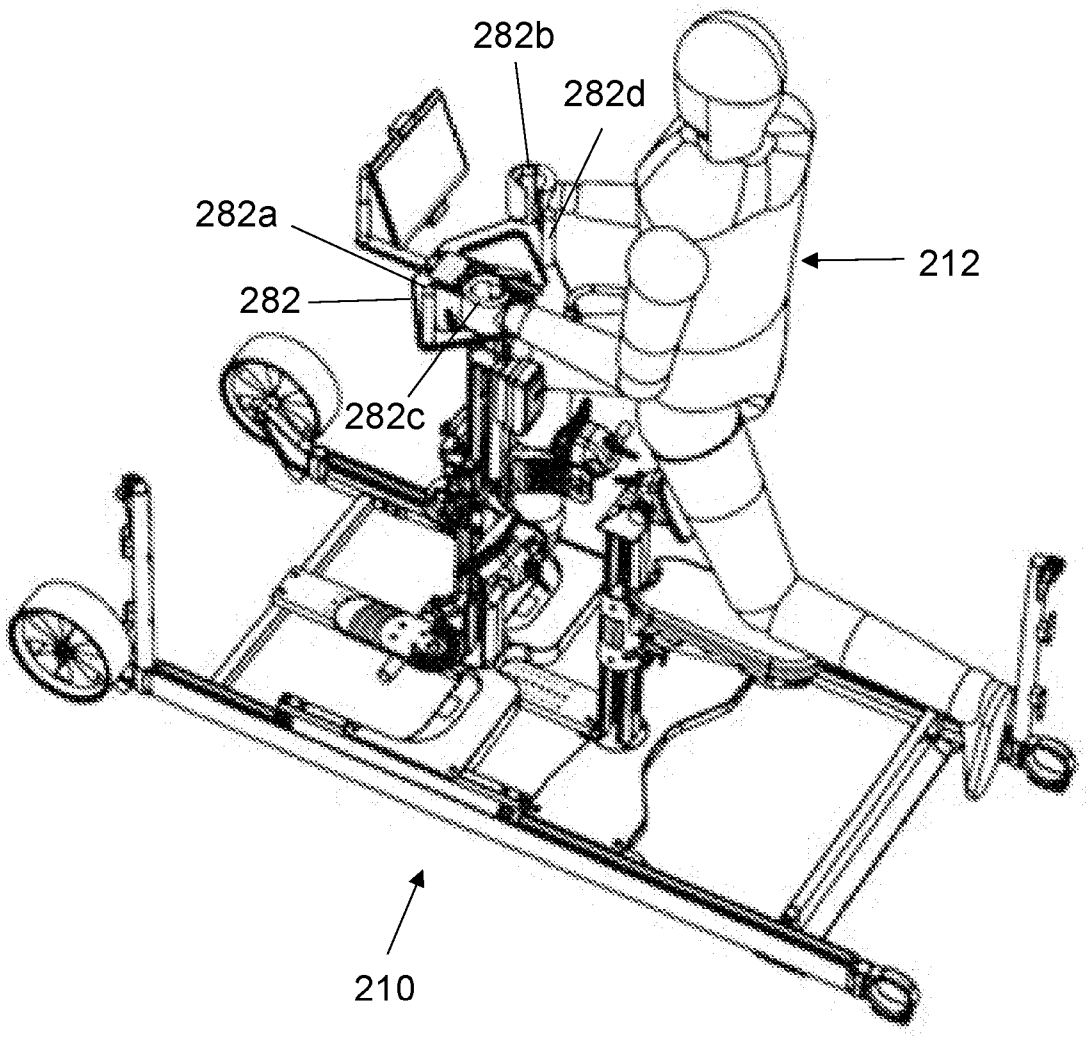

FIG. 10

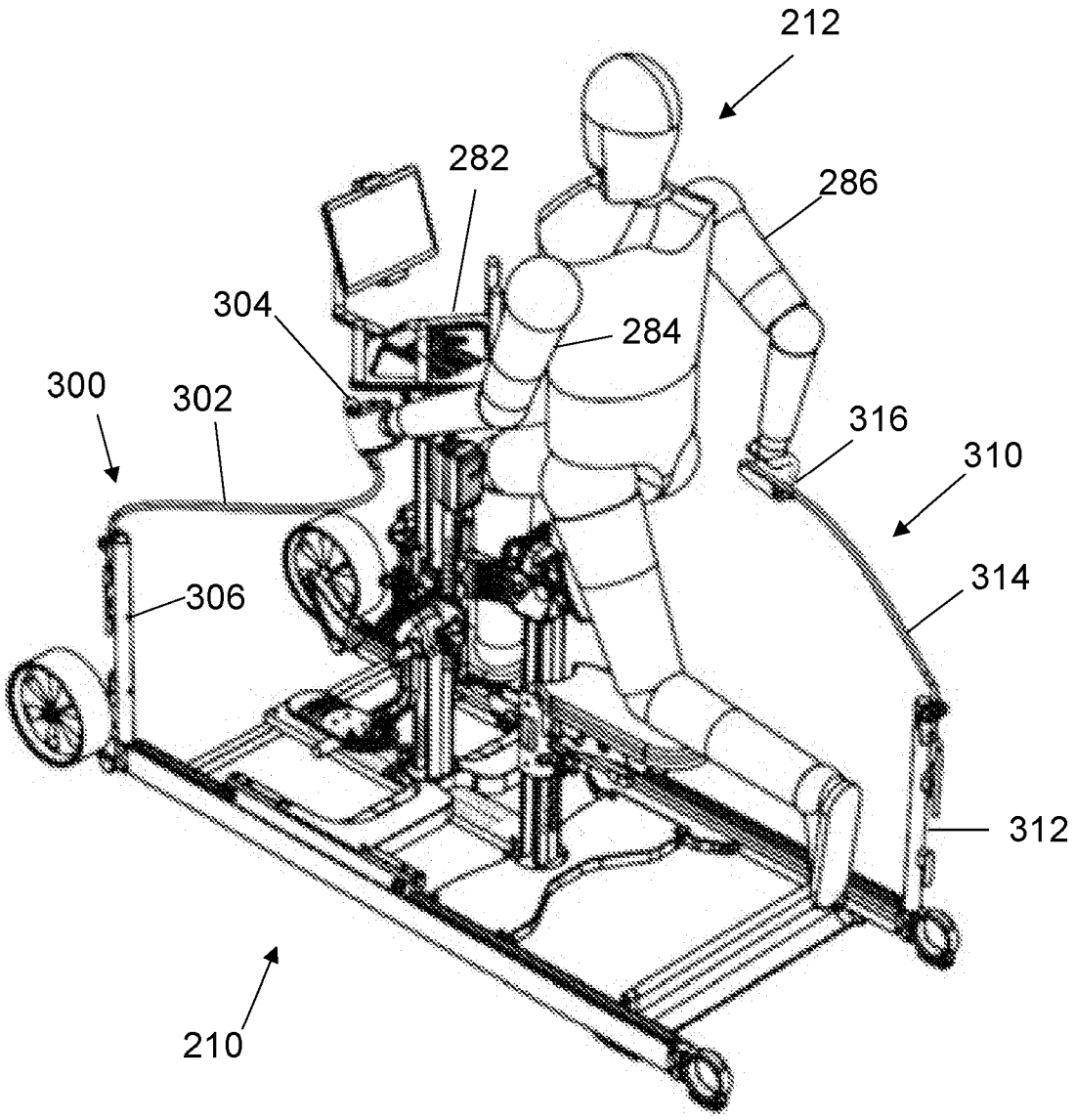

FIG. 11

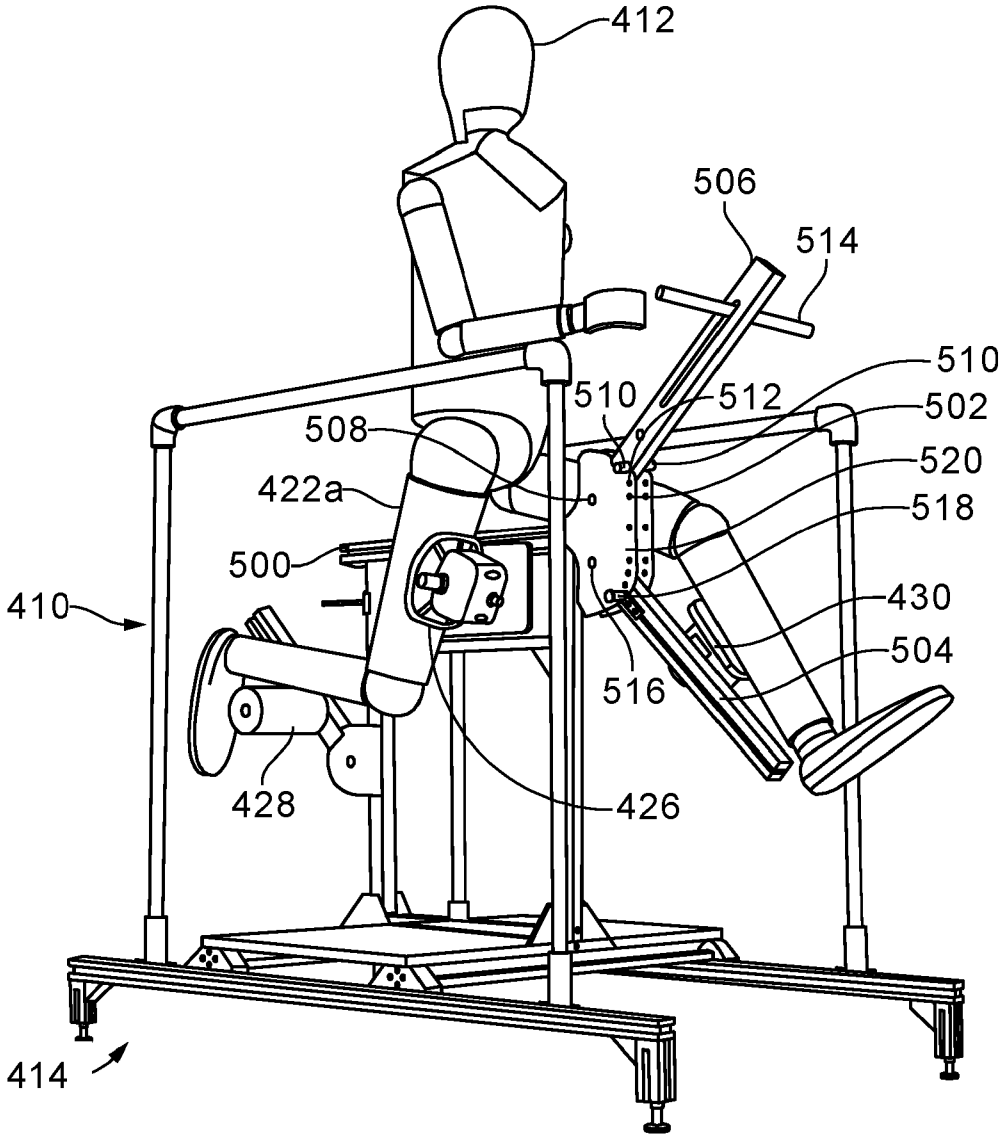
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FIG. 12

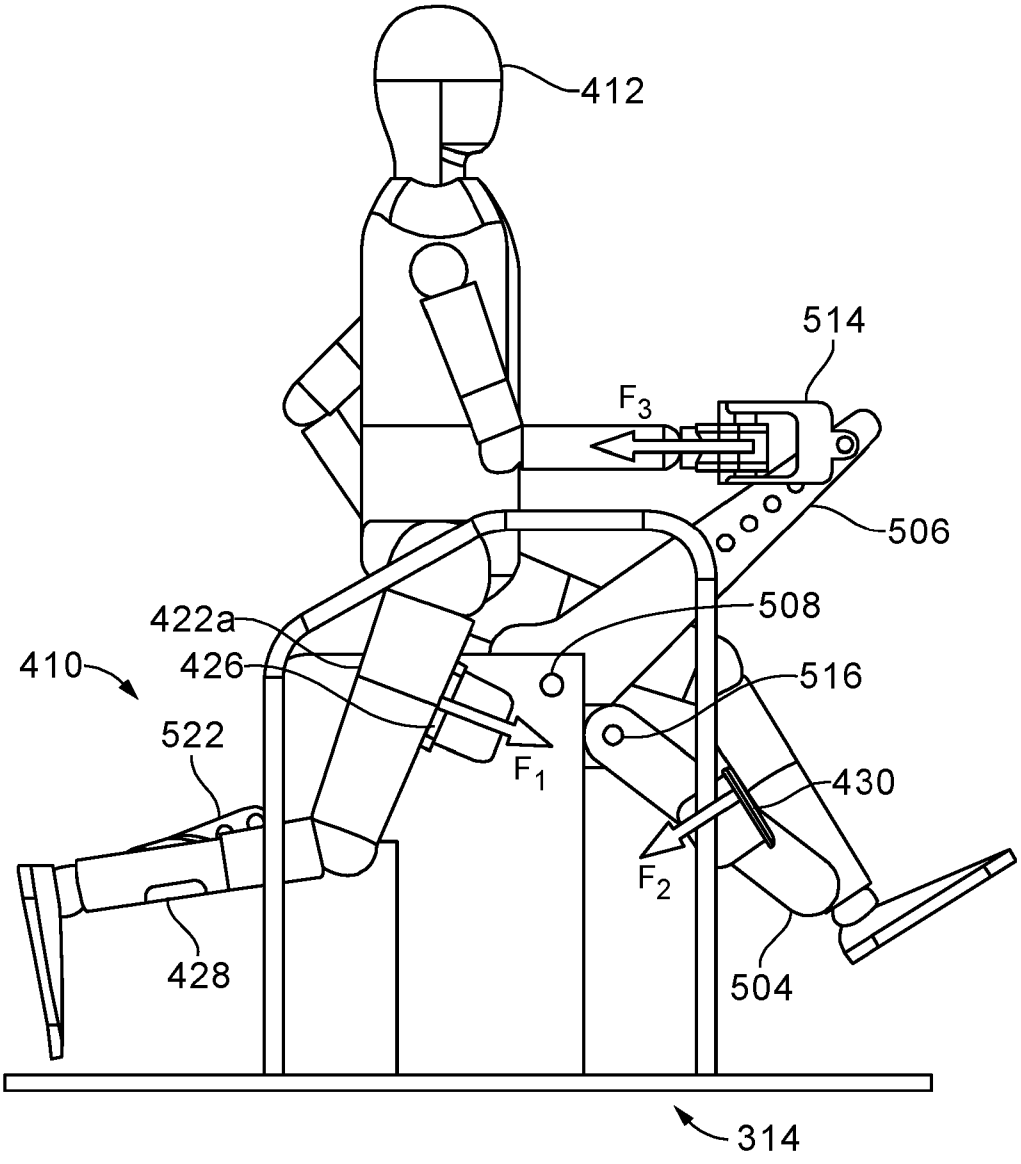

FIG. 13

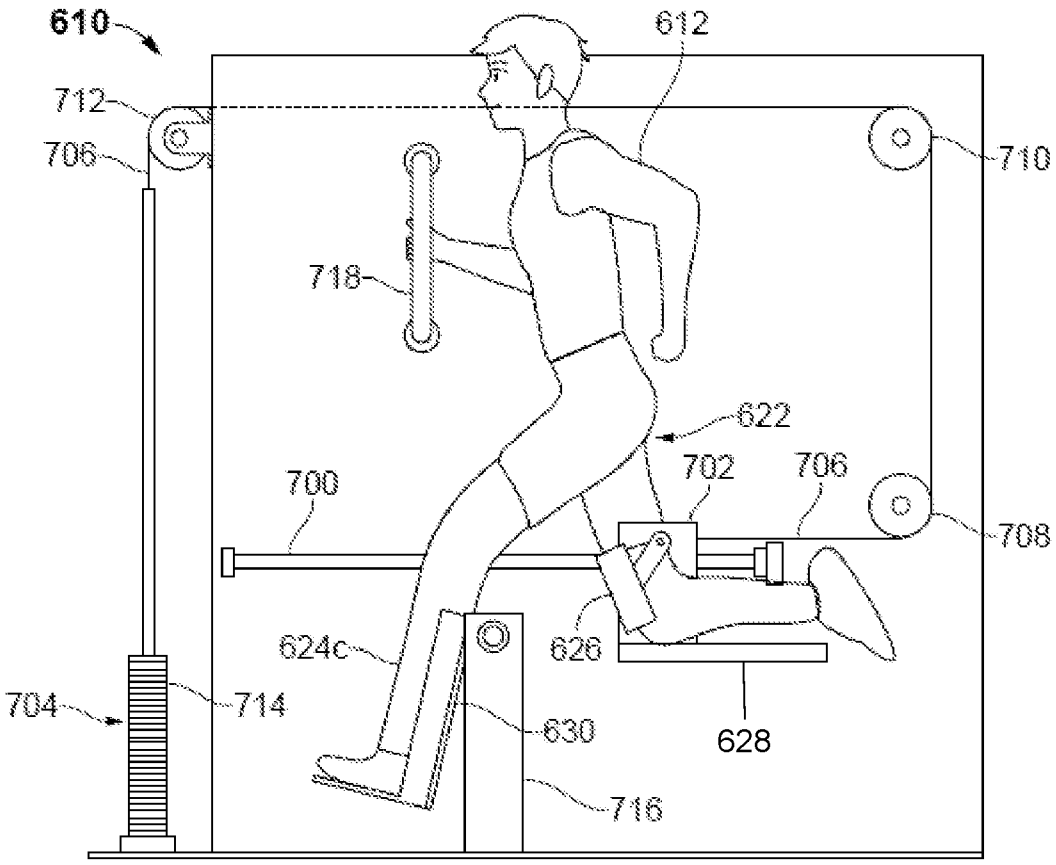
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FIG. 14

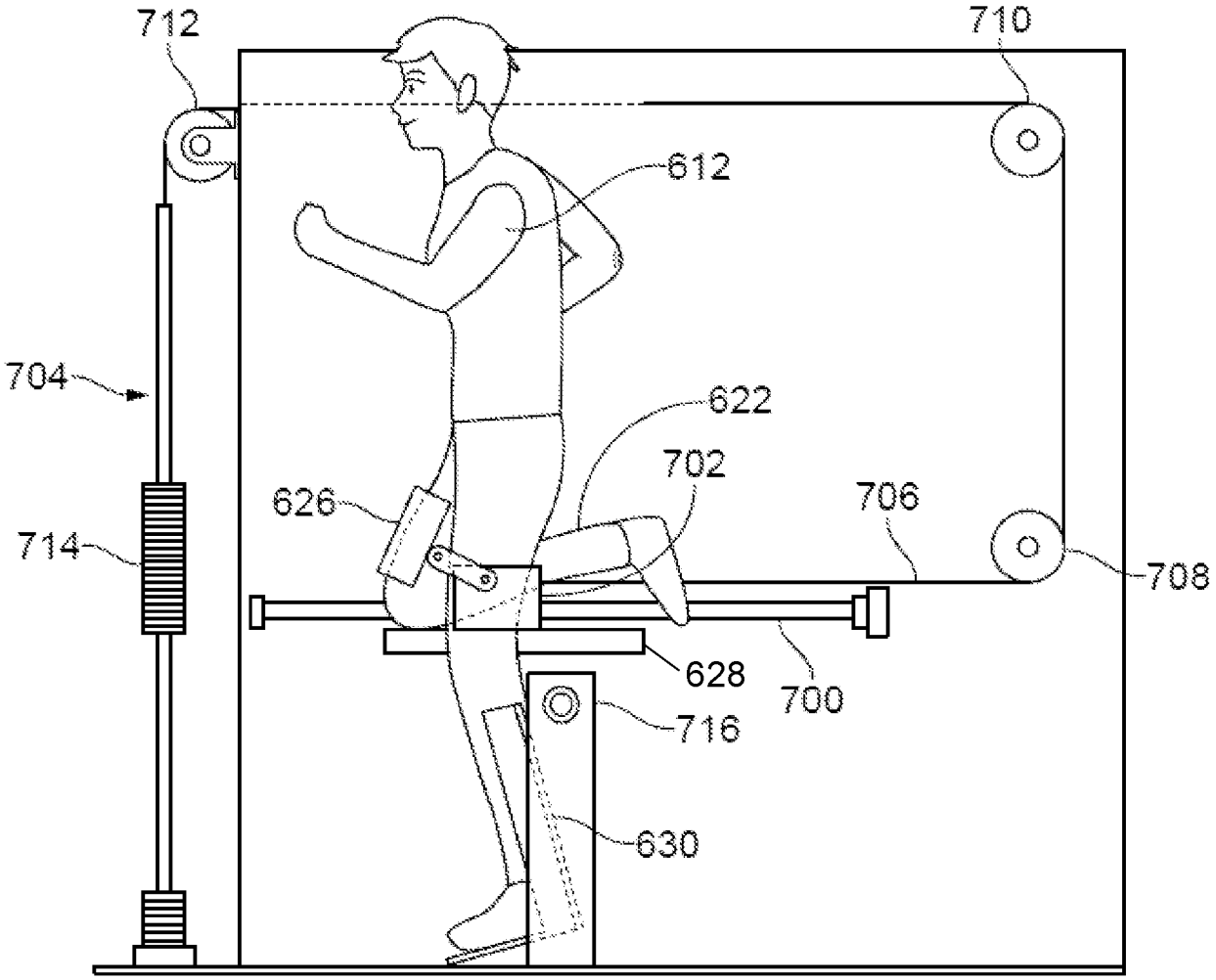

FIG. 15

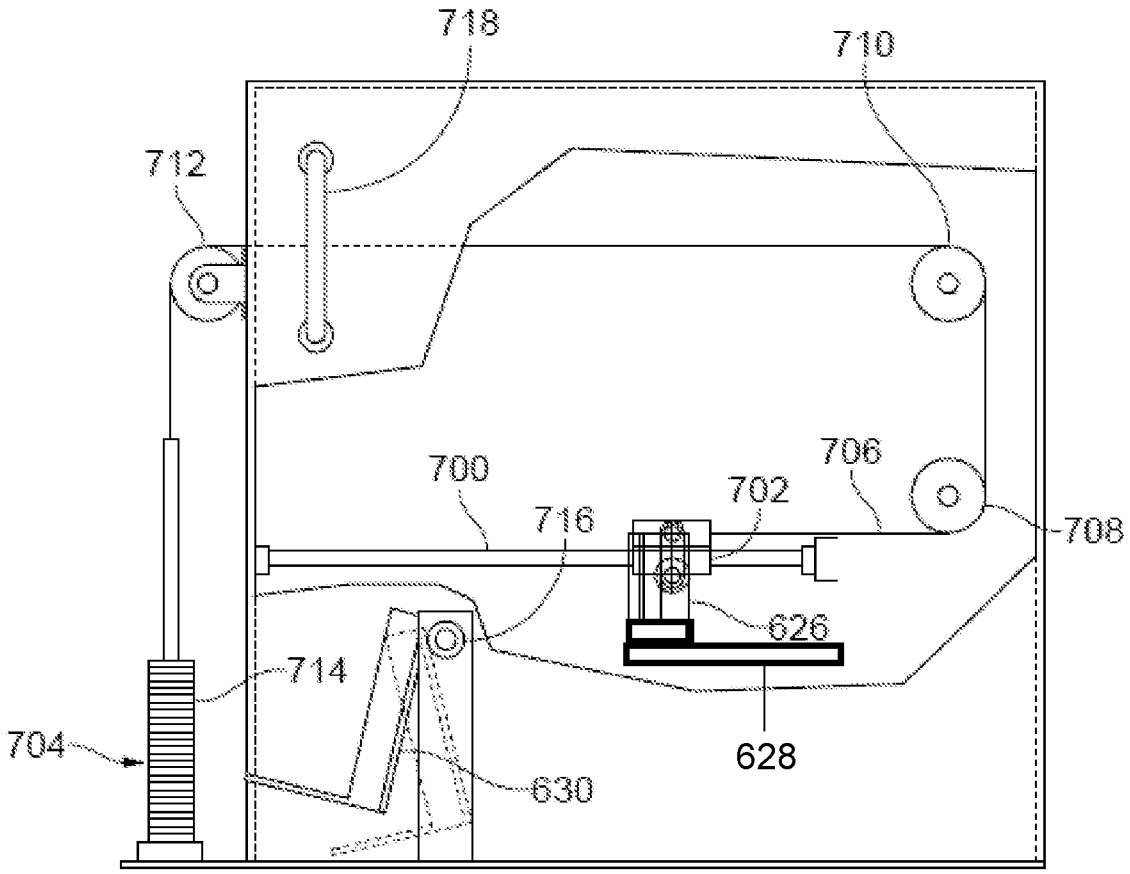

FIG. 16

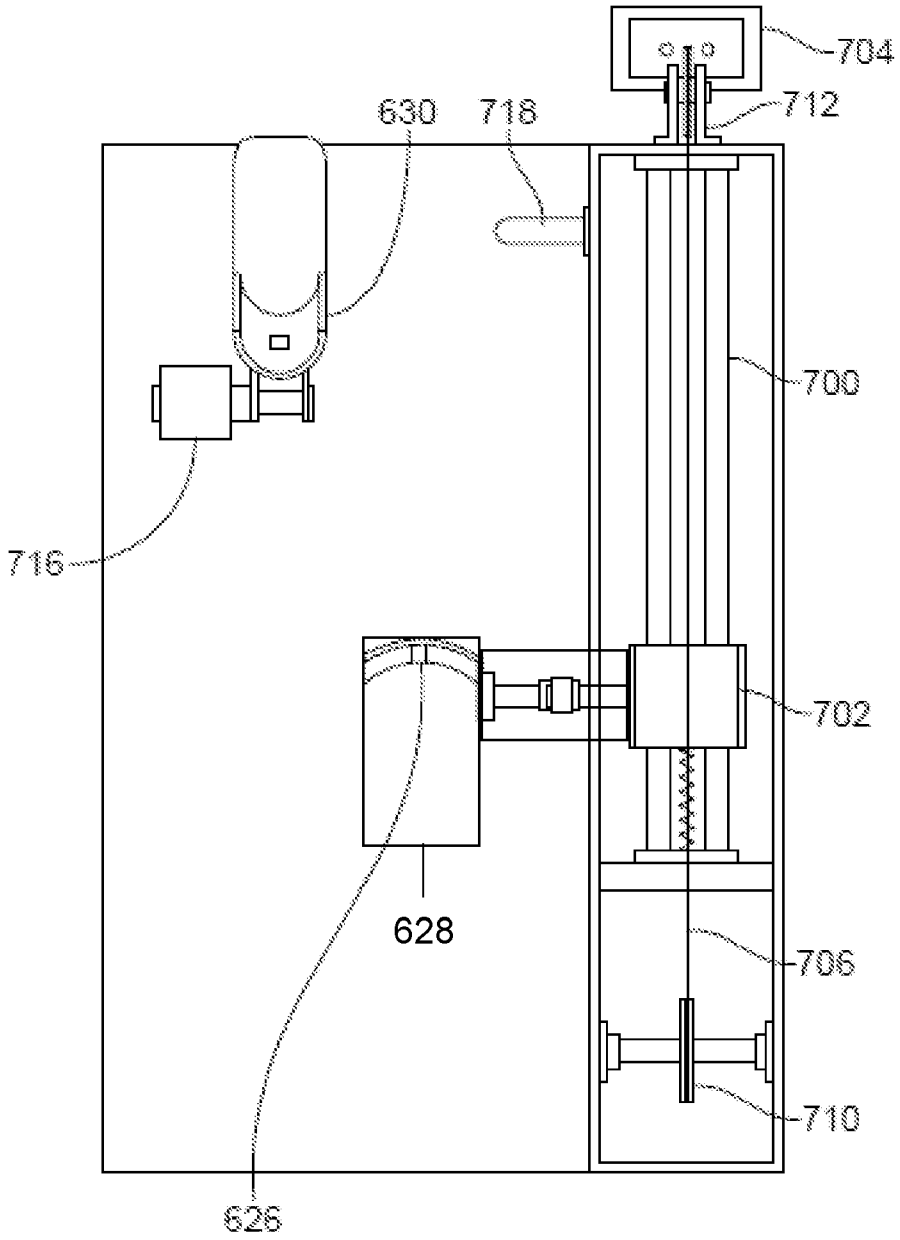

FIG. 17

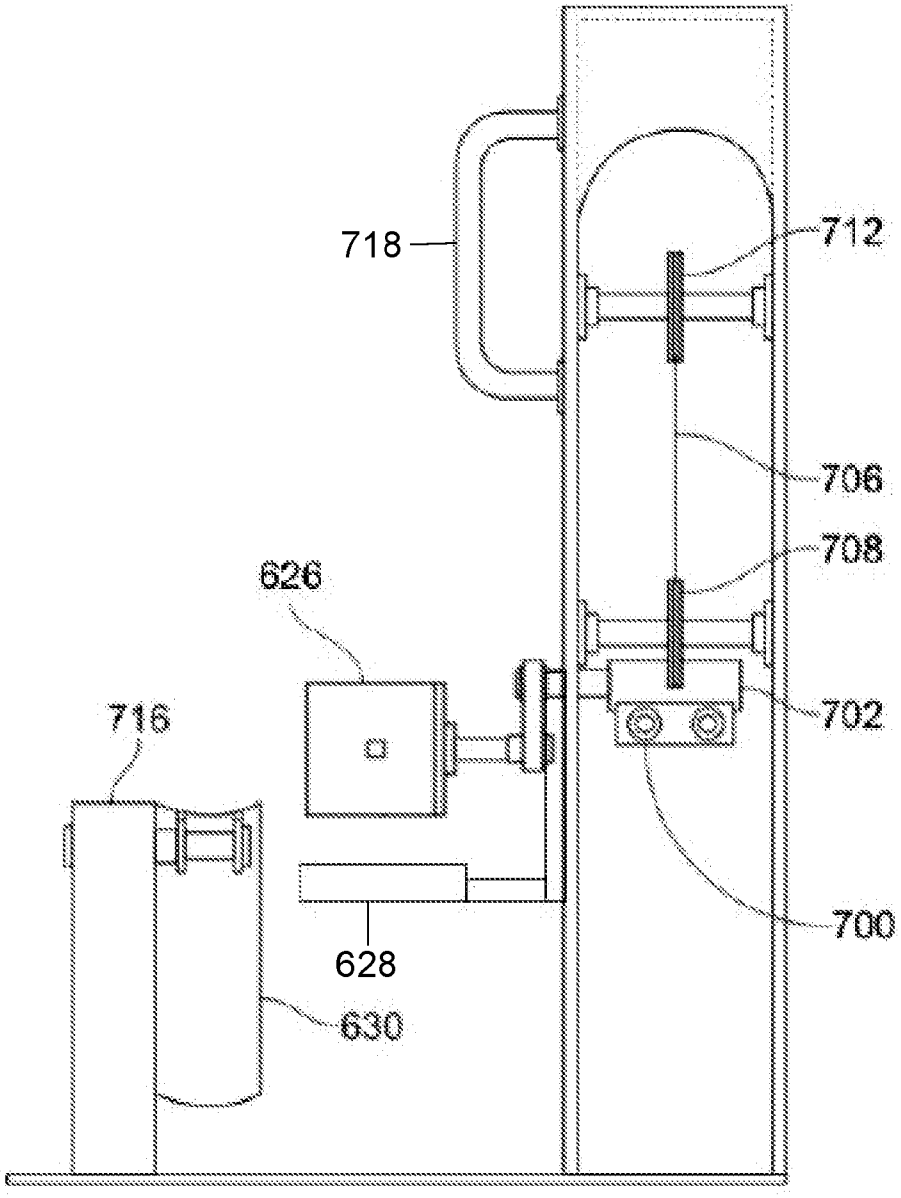

FIG. 18

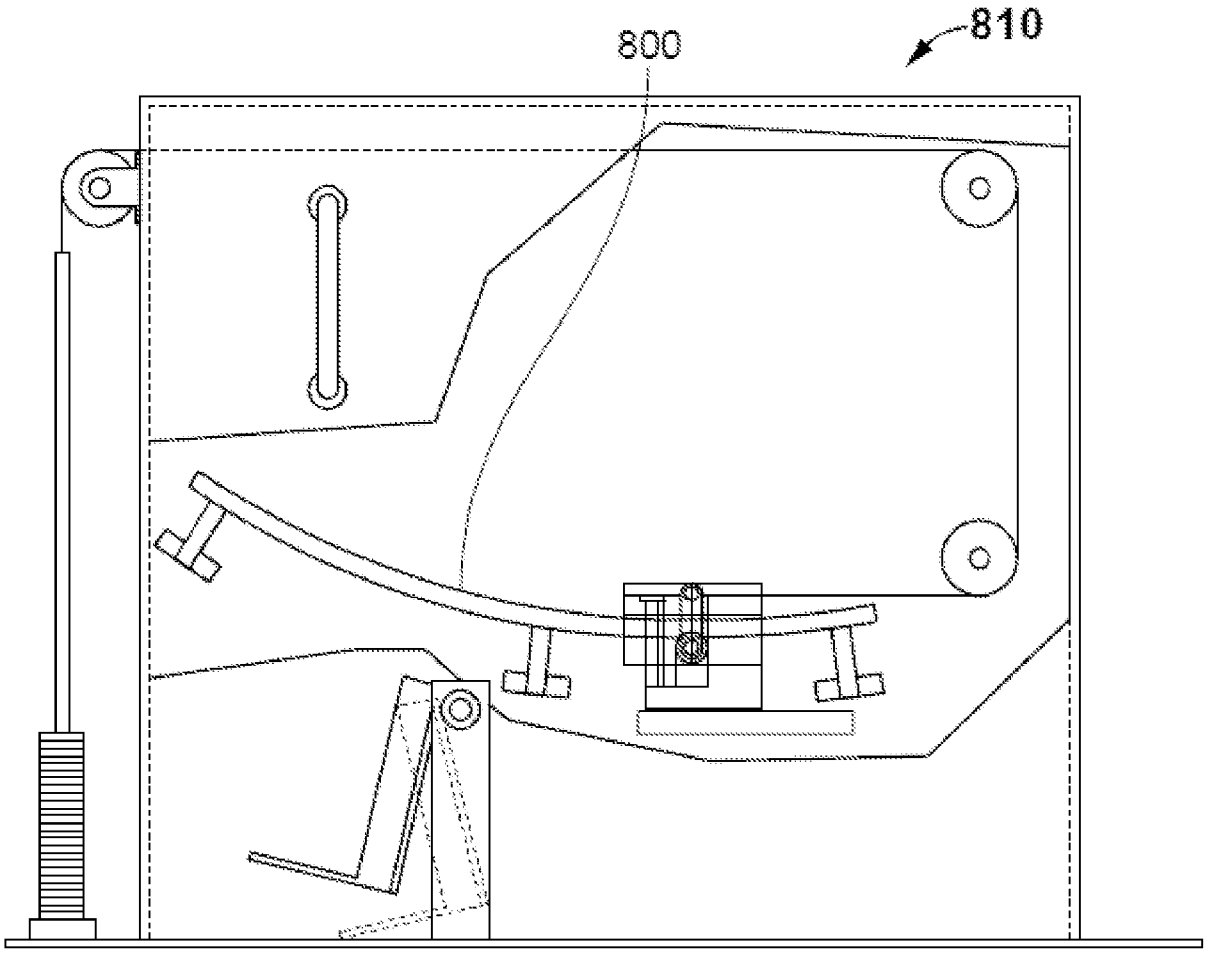

FIG. 19

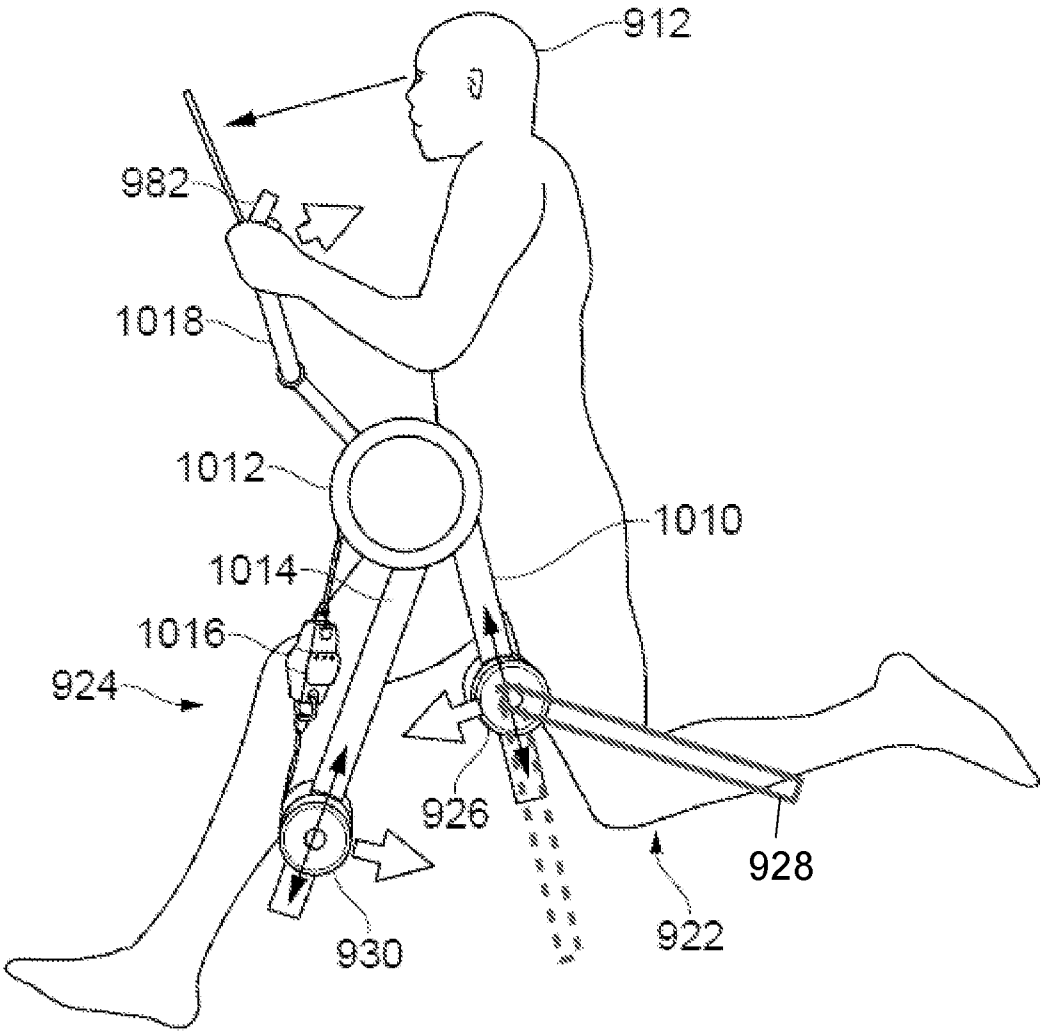

FIG. 20

APPARATUS FOR EXERCISE AND/OR FOR FITNESS ASSESSMENT

The present invention relates to apparatus for exercise and/or for fitness assessment. The invention can be used to address specific issues relating to a user's fitness for running.

In sports which involve sprinting, such as track events, rugby and football, hamstring injuries are highly prevalent. Hamstring injuries have been found to make up 12-16% of all injuries in athletes and recurrence rates are as high as 22-34%. Aside from the implications for the health of the athletes concerned, and the opportunities they lose whilst injured to achieve sporting success, hamstring injuries have major financial implications in sports such as football where the cost of injury to a high-value player can be large. It can take weeks or months to recover from a grade 2 or grade 3 muscle tear.

The hamstring muscle group comprises three muscles making up the majority of the muscle mass in the posterior thigh. The medial and lateral hamstrings are involved in flexion of the knee and extension of the hip. They are lengthened by knee extension and hip flexion.

When running, each leg goes through a cycle comprising a stance phase and a swing phase. During the stance phase, the standing foot engages with the ground, supporting the runner's weight and driving the runner forward. When the standing foot leaves the ground, it enters the swing phase in which the leg swings forward relative to the runner's trunk before returning to the ground to repeat the stance phase. Of course both legs go through the same cycle in antiphase to each other, so that for much of the cycle, one leg is standing while the other is swinging. But there is a period during the cycle in which both legs are off the ground, the old standing foot having left the ground before the new standing foot engages with it. This is known as the "double-float" phase. It is during this double-float phase that the legs of the runner reverse their directions of movement relative to the runner's trunk. This reverse in direction requires the inertia of the swinging legs to decelerate movement in one direction and accelerate in the opposite direction. This is known as the transformational zone of a movement. It is therefore called Double Float Transformational Zone (DFTZ) when referring collectively to the transformational zones of the hips, shoulders and spine which occurs during the double float phase of the running cycle.

Looking at the leg motions individually, the old standing leg, which has been pushing backward, starts to swing forward. This is also known as the early swing phase. The front leg, which has been swinging forward, starts to move backward. This is known as the late swing phase.

As running speed increases, torques at the hips on the back and front leg increase. Because the DFTZ occurs in mid-air, without any external forces acting on the limbs, the body must create its own reaction forces using swing limb momentum. During the early swing phase as the old standing leg leaves the ground, the rearward momentum is overcome primarily by the Psoas Major and Illiacus muscles (collectively referred to as Illiopsoas) which act to flex the hip and drive it forwards relative to the trunk. These muscles have their proximal attachments on the lumbar spine and the anterior pelvis, and their distal attachments on the proximal femur. Contraction of the Illiopsoas will result in hip flexion and/or lumbar spinal extension and anterior pelvic tilt. Therefore in order to efficiently and safely flex the hip relative to the trunk during running, the spine and pelvis must remain relatively stable. This can only happen if there is an equal and opposite reaction force acting on the lumbar spine and pelvis. This reaction force is provided by the Hamstrings and Gluteus Maximus of the front leg, which also have proximal attachments to the posterior pelvis, thereby acting to create posterior pelvic tilt and spinal flexion. Posterior pelvic tilt and spinal flexion is also aided by the Abdominal muscles, especially the Internal and External Obliques which pull the anterior pelvis superiorly via their distal attachment on the anterior pelvis.

The combined torques of the front and back leg cause a rotational torque on the pelvis/ lower spine which is countered by the momentum of the arms creating a top-down rotational spinal torque.

As mentioned, the back leg torque increases as running speed increases. The front leg therefore has to go through a larger range of motion faster in order to increase its torque. It is this period in the late swing phase where the hamstring muscles are most active, as the swinging leg is decelerated by the musculature to arrest its forward swing. At this stage in the running cycle the hamstrings are acting to accelerate hip extension preparatory to foot strike. It is thought that hamstring injuries are often inflicted at this point in the running cycle, whilst the muscles are undergoing an eccentric contraction, which is to say that the muscle is actively exerting a contracting force but is nonetheless being extended due to the opposed force applied to it, in this case due to the momenta of the swinging leg and associated structures. Runners who can generate higher forces in this phase of the running cycle at increased ranges of motion are able to run faster. This results in the ability to increase stride frequency without having to compromise stride length.

Risk factors for hamstring strains, such as previous hamstring injury, fatigue, reduced strength, reduced range-of-motion and altered neuromuscular function can be minimised through training and monitoring. Peak torque or force, and more importantly rate of torque/ force development, or the early intervals of peak torque/force development are shown in the literature as affected by fatigue, and correlate highly with previous hamstring strains.

It is not only the hamstrings that are vulnerable to injury during the swing phase of the running cycle. Other common injuries thought to be incurred at this point include quadriceps strains, groin strains, lower back injuries and abdominal and inguinal hernias.

Suitable testing and training of the muscles involved in running, including but not limited to the hamstring muscles, is thus important in avoiding injury, in assessing risk of injury, in rehabilitation following injury, and in training for athletic performance.

The relevant muscles including the hamstrings do not work in isolation and they should not be monitored or trained in isolation. Studies show that collectively, hamstrings, gluteus-maximus and core muscles stabilise the lumbo-pelvic region, allowing the hip-flexors to accelerate the extended trailing leg forwards. Reduced hip-extension, or weak lumbo-pelvic stabilisers, cause lumbar-hyperextension and anterior-pelvic-tilt, increasing hamstring-length and reducing gluteus-maximus activation. Increased length/load on hamstrings causes injury during sprinting and hamstring and core-strengthening are effective for patients with lower-back-pain

So an effective fitness testing or training aid needs to be capable of providing the joint positions actually encountered during the late swing phase. Isolated exercise and testing of the hamstring muscles fails to take account of the importance of other muscle groups which influence hamstring length and activation, and the risk of hamstring injury. If the synergist muscles are weak in the double-float transformational zone, and if this is the underlying cause of a hamstring strain, then using techniques that test and exercise the hamstrings in isolation may fail to diagnose and/or treat the underlying problem.

Strengthening and conditioning the hamstring muscles can reduce the risk of injury and there are known techniques for exercising this muscle group. However, these exercises isolate the hamstring, often in non-specific joint positions and muscle lengths with minimal reaction forces. Therefore, the forces achieved during these exercises are generally very low compared to those when running, and other contributing muscles and joint positions cannot be monitored or trained.

The prior art known to the applicant includes various types of apparatus to exercise the muscles of the legs, the core, and the arms that are used in running. But they are not suited to testing or simulating the action of the body during an actual running cycle and especially during the double-float transformational zone of the cycle.

US2016/0354627A1, Cygan et al., concerns a contralateral hip and hamstring training device intended to mimic the body position and biomechanics of both walking and running. The device supports the user in a lunge, with the rear leg extended backwardly and supported on the floor and with the front

foot off the floor and unsupported. The front hip is flexed through 90 degrees – that is, the upper part of the front leg is substantially horizontal. The user's weight appears to be supported through the foot of the rear leg and the underside of the upper part of the front leg. This is not presented in the document as an approximation of the loading applied to the body in the double-float transformational zone, and nor does it provide such an approximation.

US2011/0218083A1, Staff, discloses an upright gluteus isolation weightlifting machine. The user pushes a pad downwards and backwards using one leg whilst standing on the other. The stance and action are not akin to the position and action encountered in the double-float transformational zone. Somewhat similar comments apply in relation to EP2708266A1, Eccentrica SRL.

WO2009/104206A1, Cammax S.A., concerns a machine for exercising the legs that can be used in multiple different ways to exercise different muscle groups. In one configuration, the user engages a thigh rest with a first leg whilst standing on a footboard through the other leg, and then brings the thigh forward to raise a weight stack. The machine has no other form of engagement with the standing leg than the footboard. In the exercise in question, it is clear from the illustrations that the standing leg extends directly downwardly, with the user's centre of gravity being over the standing foot. This is not a posture of the type found in the double-float transformational zone.

There are other exercise machines in which the user engages with the apparatus only through footpads which are moved back and forth against a resistance force exerted by the machine to provide exercise. Examples are found in (a) GB2460238A, Salter, (b) US2008/0081740A1, Sargen et al., (c) US5603675, Wu, and (d) US5584780, Lin. Whether or not these provide worthwhile exercise, especially for those muscles involved in walking, they do not simulate the muscle action and the posture found in the double-float transformational zone whilst running.

According to a first aspect of the present invention there is an apparatus for fitness testing or exercise which has a front and a rear and which is configured to engage a forwardly-facing user in a posture in which one leg trails and the other leg leads, the apparatus comprising a structure which supports:

a rearwardly-facing trailing-leg reaction pad arranged to engage a front part of the user's trailing leg in a region at or above the knee;

an upwardly-facing trailing-leg support disposed lower than the trailing-leg reaction pad and disposed or extending rearward of the trailing-leg reaction pad to support the trailing leg below the knee, thereby maintaining the knee of the trailing leg in a state of flexion and maintaining the foot of the trailing leg off the ground; and

a forwardly-facing leading-leg reaction pad arranged forward of the trailing-leg reaction pad to engage a rear part of the user's leading leg at or below the knee;

so that the user is able to exert a forward force upon the trailing-leg reaction pad using the trailing leg and a rearward force on the leading-leg reaction pad using the leading leg.

According to a second aspect of the present invention there is an exercise apparatus which has a front and a rear and which is configured to support a forwardly-facing user in a posture in which one leg trails and the other leg leads, the apparatus comprising a structure which supports:

a rearwardly-facing trailing-leg reaction pad which is arranged to engage a front part of the user's trailing leg in a region at or above the knee and which is mounted for reciprocal movement along a path extending in a fore-and-aft direction;

a forwardly-facing leading-leg reaction pad arranged forward of the trailing-leg reaction pad to engage a rear part of the user's leading leg at or below the knee; and

a loading mechanism which exerts a rearwardly-acting resistance force on the trailing-leg reaction pad,

so that the user is able to exercise by moving the trailing-leg reaction pad forwards against the resistance force using the trailing leg.

According to a third aspect of the present invention, there is an apparatus for fitness testing or exercise which has a front and a rear and which is configured to maintain a forwardly-facing user in a posture in which one leg trails and the other leg leads, the apparatus comprising a structure which supports:

a rearwardly-facing trailing-leg reaction pad arranged to engage a front part of the user's trailing leg in a region at or above the knee;

a forwardly-facing leading-leg reaction pad arranged forward of the trailing-leg reaction pad to engage a rear part of the user's leading leg at or below the knee; and

an arrangement for engaging with a leading arm of the user on the opposite side of the user's body from the leading leg and for reacting a rearwardly-directed force exerted by the leading arm,

so that the user is able to exert a forward force upon the trailing-leg reaction pad using the trailing leg, and a rearward force on the leading-leg reaction pad using the leading leg.

Specific embodiments of the present invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

Figures 1a and 1b both depict an apparatus embodying the present invention in use, viewed from one side;

Figure 2 depicts the apparatus of Figure 1 viewed from one side and above, without a user;

Figure 3 depicts the apparatus of Figure 1, viewed from one side and from in front;

Figure 4 depicts the apparatus of Figure 1, viewed from one side and the rear;

Figure 5 depicts the apparatus of Figure 1 being trundled from one place to another;

Figure 6 depicts a cross-section through a rail of the apparatus of Figure 1 and through a first carriage riding on the rail;

Figure 7 depicts a section through the rail and first carriage of Figure 6, but the sectional plane in this drawing runs fore-and-aft;

Figure 8 depicts a section through a force-measurement apparatus;

Figure 9 is an exploded depiction of the force-measurement apparatus;

Figure 10 depicts a second apparatus embodying the present invention, viewed from one side and above;

Figure 11 depicts the apparatus of Figure 10, viewed from one side and above, being used with tethers for the hands;

Figure 12 depicts a third apparatus embodying the present invention, viewed from one side and in front;

Figure 13 is a schematic depiction of the Figure 12 apparatus, viewed from one side;

Figure 14 depicts a fourth apparatus embodying the present invention, viewed from one side;

Figure 15 is similar to Figure 14 but shows the apparatus at a different position in its operating cycle;

Figure 16 is a further side view of the apparatus of Figure 14, a user being omitted from this drawing;

Figure 17 depicts the apparatus of Figure 14 viewed from above;

Figure 18 depicts the apparatus of Figure 14 viewed from in front;

Figure 19 depicts a fifth apparatus embodying the present invention, viewed from one side; and

Figure 20 depicts a sixth apparatus embodying certain aspects of the present invention in use.

The apparatus 10 depicted in Figures 1 to 5 is usable to measure forces exerted by the legs whilst in a body position which simulates the double-float transformational zone. It may be used to measure the muscular performance of a healthy user 12 and to monitor the recovery of an injured one, and it may be used in exercise.

The apparatus 10 comprises a frame 14 which in the present example is floor standing and which supports a plurality of pads and supports through which the apparatus engages with the body of the user to define the user's body position and to enable measurement of forces generated by the user 12.

The apparatus 10 has a front 16 and a rear 18 and the user 12 faces forwardly as shown in Figures 1a and 1b. During exercising or fitness testing, the user's trunk 20 is upright. One leg 22 trails and the other leg 24 leads. The trailing leg 22 is angled rearwardly from the trunk 20 and engages with a trailing-leg reaction pad 26 and with a trailing-leg support 28. The upper part 24a of the leading leg 24 is angled forwardly from the trunk 20 and the leading leg engages with a leading-leg reaction pad 30 and with a leading-foot support 32.

The trailing-leg reaction pad 26 faces rearwardly, to engage with a front part of the trailing leg in an upper region 22a of the leg, above or at the knee and below the hip. The trailing-leg support 28 faces upwardly and is arranged to support the knee 22b and/or the lower part 22c (shin) of the trailing leg. The trailing leg 22 is thus maintained in a condition in which its upper portion 22a extends downwardly and rearwardly from the hip and its knee 22b is flexed, the lower part 22c of the trailing leg extending backwardly (although it may be inclined downwards from the knee 22b) with the trailing foot 22d being off the ground, and unsupported. The user's weight is partly supported through the trailing-leg support 28 but is not supported by the trailing foot 22d.

The leading-leg reaction pad 30 faces forwardly to engage with the rear of the leading leg 24 in a lower region 24c of that leg, from the knee 24b downwards. The leading-foot support 32 faces upwardly to support the leading-foot 24d, through which the user's weight is partly supported.

While the apparatus provides for adjustment of the positions of the supports 28, 32 and of the reaction pads 26, 30, their relative positions are, in the illustrated (and typical) configuration, such that the trailing-leg reaction pad 26 is higher than the trailing-leg support 28.

The trailing leg 22 engages the trailing-leg support 28 rearward of the trailing-leg reaction pad 26. This may be because the trailing-leg reaction pad 26 is itself arranged rearward of the trailing-leg reaction pad 26, but in the present embodiment the trailing-leg support 28 is seen to be elongate in the fore-and-aft direction, so that a part of it lies forward of the trailing-leg reaction pad but it nonetheless extends to a more rearward region where it engages the leg.

The leading-foot support 32 is lower than the leading-leg reaction pad 30.

The leading-leg reaction pad 30 is forward of the trailing-leg reaction pad 26.

The trailing-leg support 28 is higher than the leading-foot support 32.

The frame 14 must be configured to carry the reaction pads 26, 30 and the supports 28, 32 in the required relative positions, but beyond that its form may vary greatly from one embodiment to another, and in fact multiple different frames are depicted and described herein. In the present embodiment there is a ground-engaging, tubular, "U" shaped base frame 34 whose free ends each carry a respective ground wheel 36. At the other end of the base frame 34 is a grippable portion 38 which is upturned so that it can easily be grasped and lifted. The apparatus 10 is thus able to be easily trundled from one place to another as depicted in Figure 5. Lifting the grippable portion 38 causes the ground wheels 36 to engage the ground. When the frame 34 is lowered to the ground the wheels 36 are lifted and the base frame rests stably on the ground. Front and rear cross members 40, 42 are provided across the base frame 34 and carry a rail 44 extending in the fore-and aft direction. The rail 44 in its turn supports an upright front column 46 and an upright rear column 48.

The front column 46 is movable fore-and-aft along the rail 44, engaging with it through a lockable first carriage 50. The front column 46 extends upwardly from the first carriage 50. The first carriage 50 has a through-going opening (indicated at 52 in Figures 6 and 7) through which it surrounds and receives the rail 44. The formation of the rail 44 and of the first carriage 50 is such that the first carriage 50 is prevented from rotating about the rail 44. Figures 6 and 7 in particular depict the relevant features. The first carriage 50 is seen to carry left- and right-hand rollers 53, 54 running in complementary longitudinal channels 56, 58 on either side of the rail 44. This provides for smooth, low-friction movement of the first carriage 50 when required, and defines the first carriage's rotational position with respect to the rail 44. The first carriage 50 has a user-operable locking mechanism by which it is to be locked in the desired fore-and-aft position. In the present embodiment this takes the form of an

index pin 60 carried by the first carriage 50 and selectively engageable in any of a number of locking openings 62 provided at intervals along the length of the rail 44.

The rear column 48 is in this embodiment not capable of movement along the rail 44, instead being mounted to the rail 44 through a fixed end cap 64.

The present embodiment comprises left and right leading-leg reaction pads 30a, 30b arranged to either side of the front column 46 (see e.g. Figure 2), and a corresponding pair of left and right leading-foot supports 32a, 32b likewise arranged to either side of the front column 46. Hence, without adjustment of the apparatus 10, the user can move between the stance seen in Figure 1a in which the left leg is the leading leg, engaging with reaction pad 30a, and the stance seen in Figure 1b in which the right leg is the leading leg, engaging with reaction pad 30b. The leading-leg reaction pads 30a, 30b are each carried on a second carriage 66 which is movable up and down the front column 46 to adjust their height. The second carriage 66 is similar to the first carriage 50 in the manner in which it is able to move without rotating, and to be locked in a selected position. These aspects will not be described again. The leading-leg reaction pads 30a, 30b are in the present embodiment carried on respective bracket arms 68a, 68b (see Figure 4 in particular) which project rearwardly from the second carriage 66.

The leading-foot supports 32a, 32b are adjustable in height independently of the leading-leg reaction pads 30a, 30b. In the present embodiment each is carried by a respective stem 70a, 70b (see Figure 3) each having an upper part 72 which is straight and upright, running parallel to the front column 48, and an elbow leading to a forwardly-inclined lower part 76 carrying the foot support 30a or 30b (see Figure 2). The straight upper part 72 of each stem 70a, 70b extends through a respective, vertically-extending opening in the second carriage 66, forming a sliding fit therein, and terminates in the upward direction in a third carriage 78. The third carriage 78 is mounted upon and movable along the front column 48. It is similar to the first carriage 50 in the manner in which it is able to move without rotating, and to be locked in a selected position. These aspects will not be described again. It will be apparent from the drawings that by moving the third carriage up and down, the height of the leading-foot supports 32a, 32b is varied.

The trailing-leg support 28 is height adjustable. It is carried by a fourth carriage 79 mounted on the rear column 48. The fourth carriage 79 is similar to the first carriage 50 in the manner in which it is able to move without rotating, and to be locked in position. These aspects will not be described again. The fourth carriage 79 comprises a rearwardly-extending arm 80 which carries the trailing-leg support 28.

The apparatus provides a handle 82 to be grasped by the user 12 in operation, which can help the user 12 to maintain a desired posture, which may be a posture that mimics the hand and arm positions during the double-float transformation zone. In the present embodiment, the handle 82 is disposed above the leading-leg reaction pads 30a, 30b. Specifically, the handle 82 is mounted on the front column 46. A lockable telescopic arrangement 84 permits adjustment of the handle height. In use, as depicted in Figure 1, a leading arm 84 (on the side of the body opposite to the leading leg) grasps the handle 82 so that its hand is extended in front of the user's trunk and its elbow is flexed, while trailing arm 86 is in this example unsupported but can again be positioned by the user 12 to simulate running.

During testing or exercise, the user 12 typically exerts a rearward force on the handle 82 which mimics the muscular action during the double-float transformational zone of the running gait, as the leading hand, which is initially moving forwards, accelerates rearwardly. This action of the leading arm 84 also stabilises the user's torso whilst exercising. It is not vital that the means used to react the force exerted by the leading arm should use a fixed handle. Another embodiment (not illustrated) uses instead a forwardly-facing reaction pad placed behind the upper arm of the user 12, so that the necessary rearward force can be exerted on the reaction pad using the upper arm, without the involvement of the hand. Another embodiment (not illustrated) uses a cuff placed around the upper part of the leading arm 84 and linked to a forward-going tether, such as a rope or line, so that rearward force exerted by the leading arm 84 is reacted through the tether.

The force exerted by the leading arm need not in every case be rearward. Other exercise protocols may require the user to push forward with one or both arms.

The frame 14 provides multiple adjustments, enabling the apparatus 10 to be configured (a) for users of a range of sizes and (b) to provide a given user with a range of different postures.

By moving the first carriage 50 fore-and-aft, the user can adjust the longitudinal separation of (a) the trailing-leg reaction pad 26 and the trailing-leg support 28 from (b) the leading-leg reaction pad 30 and the leading-foot support 32. In this way the posture of the user is adjustable, in particular to increase or decrease the angle between the upper part 22a of the trailing leg and the upper part 24a of the leading leg.

The height of the leading foot 24d relative to the trailing foot 22d is adjustable by moving the leading-foot supports 32a, 32b up and down.

The location of the leading-leg reaction pad 30 along the lower part 24c of the leading leg 24 is adjustable by moving that part up and down.

The location of the trailing-leg reaction pad 26 along the upper part 22a of the trailing leg 22 is adjustable by moving the trailing-leg support 28 up and down.

The apparatus of Figures 1 to 5 is static, in the sense that its parts are not intended to be moved by the user 12 whilst fitness testing or exercising. Accordingly, the action of the muscles during use of this apparatus is isometric – the muscles exert forces but do not undergo extension or contraction. Use of the apparatus involves the user 12 exerting him or herself to apply forces to the trailing-leg reaction pad 26 and to the leading-leg reaction pad 30. In the present embodiment, the apparatus is configured to measure these applied forces.

Figures 8 and 9 depict a force-measurement arrangement 89 through which the trailing-leg reaction pad 26 is mounted. The arrangement comprises an enclosure 90 having an open front face. A rear face 92 of the trailing-leg reaction pad 26 carries an upstanding wall 94 received through the said open face to locate the trailing-leg reaction pad 26 with respect to the enclosure 90 while permitting it to transmit force to a pressure sensor in the form of a load cell 96 which is mounted between a pair of fixation plates 98 such that force applied to front face 100 of the trailing-leg reaction pad 30 is reacted to the enclosure 90 through the load cell 96, which thus provides an output representative of said force.

The leading-leg reaction pads 30a, 30b are mounted through similar force-measurement arrangements 102a, 102b (see Figure 2).

In this embodiment, the apparatus thus generates at least two force sensor outputs, one from the active leading-leg reaction pad 30a or 30b and one from the trailing-leg reaction pad 26. Other sensor data may be obtained. In the present embodiment each of the reaction pads 26, 30 is mounted in a manner that enables it to turn somewhat to align with the leg. The angles of the reaction pads may be sensed e.g. through an inclinometer 104 incorporated into each force-measurement arrangement 89 (see Figure 9). Other means may be used to sense the reaction pads' angular positions. This angular sensor data provides an indication of the inclination of the upper part 22a of the trailing leg 22, and of the lower part 24c of the leading leg 24.

The sensor data is digitised for display and analysis, typically using an onboard digital device. The onboard digital device is typically connected to a network. In the present embodiment the structure forming the handles 82 is configured also to mount a suitable onboard digital device. This structure has an "L" form, viewed from one side, with the upright limb of the "L" carrying a mounting plate 106 (see Figure 3) for a device such as a tablet computer (not shown in Figures 1 to 5). The onboard digital device can provide a screen serving to provide the user 12 with prompts, and to display sensor data. The data may be transferred to a local area network and/or to a wide area network, for storage, usage

and further analysis. Thus, for example, the data may be stored in local servers and/or in the cloud, and may be accessed through a dedicated application. Forces applied to the two reaction pads 26, 30 may be displayed and analysed separately, or may be added together to give a measure of total force exerted. Data will typically be graphed, and may be displayed to the user in real time. In some trials the user may, for example, be provided with on-screen and/or audible prompts to make repeated muscular contractions at intervals, with data including the rate of change of force (the first time-differential of the force) and the peak force being measured. The changes in such metrics over repeated contractions may be calculated and assessed. Data from multiple trials carried out over a period of time may be stored, as a basis for assessment of changes in the performance and fitness of the user 12.

The apparatus 10 allows for lumbo-pelvic stabiliser and hip flexor co-contractions to occur simultaneously, allowing accurate monitoring of intersegmental strength and range of motion, whilst allowing the user to build relative strength and better neuromuscular control.

While some exercises practised using the apparatus 10 involve the arms 84, 86 of the user 12 being arranged as depicted in Figure 1, with one leading and one trailing, other exercises involve both hands of the user gripping the handle 82. In this mode, the user can be directed to push forwards with both arms, to maximise loading of the hamstrings of the leading leg 24. Loading of hip flexors of the trailing leg 22 is reduced. And the user can be directed to pull with the arms 84, 86, thereby reducing loading of the hamstrings of the leading leg 24 and increasing loading of the hip flexors of the trailing leg 22. These exercises can help to determine which specific muscle groups of the legs might be weak and require exercise or other therapy. In some embodiments force(s) applied to the handle 82 may be measured. In other exercises the user may grip the handle 82 with both hands and be directed to pull with the leading arm and to push with the other arm, exerting a rotational torque which anchors the pelvis and allows force generated with the legs to be maximised.

Figures 10 and 11 depict a second apparatus 210 embodying the invention which is similar to that of Figures 1 to 5 but has a different handle arrangement 282, which provides a left- and right-hand pair of upright handles 282a, 282b to be grasped with the left and right hands respectively. These handles are well adapted for use in exercises requiring the user to push rather than to pull with the arms/hands. In fact in this embodiment there is a further handed pair of upright handles 282c, 282d inboard of the first pair, to give flexibility in the locations of the hands.

In Figure 11 the user 212 is not holding the handle arrangement 282 but instead holds a flexible leading-arm tether 300 in the leading hand. The leading-arm tether comprises a flexible line 302 and a hand grip 304, and extends from an upright post 306 toward the front of the apparatus 210, so that

it is able to react a rearward force exerted by the user's leading arm 284. In place of the hand grip 304, the leading-arm tether may terminate in a cuff (not shown) to be placed around the leading arm 284 above the elbow.

The Figure 11 embodiment additionally provides for reaction of a force exerted by the trailing arm 286 through a flexible trailing-arm tether 310 leading from an upright post 312 at the rear of the apparatus 210. The trailing-arm tether 310 comprises a flexible line 314 and a hand grip 316 to be held in the hand of the trailing arm 286 and is able to react a forwardly-directed force exerted by the trailing arm. In place of the hand grip 316, the trailing-arm tether 310 may have a cuff (not shown) for placement around the trailing arm 286 above the elbow.

Figures 12 and 13 depict a third apparatus 410 embodying the present invention, whose frame 414 differs from the frames of the earlier embodiments. Whereas in the first two embodiments, adjustments of the frame and of the parts supported upon it are made through linear movements, the third apparatus 410 permits adjustments largely through rotational movements. An elevated chassis 500 carries at its front a parallel pair of plates 502 between which are mounted a leading-leg support bar 504 and a handle support bar 506.

The handle support bar 506 projects forwardly and upwardly from the chassis 500, being able to turn about a pivot 508 but lockable in a chosen rotational position by means of a pin 510 received through any one of a number of locking holes 512 through the plates 502. A handle 514 is carried toward a front end of the handle support bar 506, to be grasped by the leading hand of the user 512.

The leading-leg support bar 504 projects forwardly and downwardly from the chassis 500 being able to turn somewhat about a pivot 516 and lockable in a chosen rotational position by means of a pin 518 insertable through any of a number of locking holes 520. Mid-way along the leading-leg support bar 504 is leading-leg reaction pad 430, which is formed similarly to the reaction pads of earlier embodiments and which serves to measure force applied by the leading leg 426.

Trailing-leg reaction pad 426 is carried in this embodiment to the side of the chassis 500, to engage the upper trailing-leg 422a. Trailing-leg support 428 is carried on a trailing arm 522 which is able to turn somewhat and to be locked, to provide for adjustment of the location of the trailing-leg support 428.

In Figure 13, arrows indicate the forces F1, being measured by the trailing-leg reaction pad 426, and F2, being measured by the leading-leg reaction pad 430. Additionally in this embodiment provision is made to measure a rearward force F3 exerted by the leading hand. The forces F1 and F2 may be resolved into opposed horizontal components and added, to give a total force exerted by the user

412. Alternatively or additionally, they may be expressed or even measured as a total torque acting about a notional axis at hip level.

The above-described embodiments are used to take measurements of force whilst the user 12, 212, 412, is essentially static. The key parts of the device with which the user engages remain in a fixed spatial relationship to one another during testing or exercise (although this relationship can be adjusted as explained already) and the action of the user's musculature is essentially isometric. Other embodiments of the invention provide for the user to exercise by repeatedly moving the trailing leg forwards against a resistance force, and then backwards to repeat the action. The apparatus 610 depicted in Figures 14 through 18 provides an example.

Here, trailing-leg reaction pad 626 and trailing-leg support 628 are movable along a generally horizontal path defined by a rail 700. The trailing-leg reaction pad 626 and the trailing-leg support 628 are carried on pad carriage 702 which receives and slides upon the rail 700, and is able to turn somewhat so that its inclination matches that of the upper part of the trailing leg 622. In fact in the present embodiment the rail 700 is formed by a parallel pair of bars, as seen in Figure 17. A rearwardly-acting resistance force is applied to the trailing-leg reaction pad 626 through a loading mechanism 704. In the present embodiment the loading mechanism 704 uses weights, although other types of loading mechanism may be used in other embodiments (e.g. spring mechanisms, or frictional mechanisms). A load line 706 leads rearwardly from the pad carriage 702 and then around an arrangement of pulleys 708, 710, 712 to a weight stack 714, so that moving the pad carriage 702 forwardly involves lifting a selected number of weights from the stack 714.

The apparatus 610 further comprises leading-leg reaction pad 630 which depends from an upright post 716. The leading-leg reaction pad is able to swing through a limited angular range, to accommodate changes in angle of the lower leading leg 624c during the exercise. A handle 718 is grasped with the leading hand in use, to stabilise the user 612.

In operation, the user 612 repeatedly pushes the trailing-leg reaction pad 26 forwards against the resistance force, thereby providing exercise. The leading leg is restrained in a largely fixed position by the leading-leg reaction pad 630 but is able to bend and straighten somewhat to simulate its movement through the double-float transformational zone. The handle 718 enables the user to stabilise the body and engage the muscles of the core, allowing the user to more powerfully drive forwards with the trunk and rear leg. This movement is assisted by the backward force exerted by the leading leg 624 against the leading-leg reaction pad 630 whilst pulling backward on the handle 718 with the leading arm. The leading-leg reaction pad 630 and the handle 718 act as anchor points to replicate the joint positions of the leading leg 624 and the leading arm during the double-float phase.,

allowing the user to powerfully drive the trailing leg 622 forwards, mimicking the action needed to recover the trailing leg 622 during the double-float phase. Indeed, during the action the user's trunk translates forwards relative to the leading leg 624 and the trailing leg 622 translates forward relative to the trunk, as is apparent from a comparison of Figures 14 and 15. The exercise mimics the joint positions and coordinated muscle contractions of arms, legs and trunk during the double-float transformation.

The apparatus 610 is configured such that the left leg 624 of the user 612 leads and the right leg 622 trails. To provide for the opposite stance, where the right leg leads, the components shown to the left in Figure 18 – post 716, trailing-leg reaction pad 626, leading-leg reaction pad 630 and handle 718 – may be provided with oppositely-handed counterparts on the right side of the rail 700. In this case the pad carriage 702 will carry a left and a right-handed trailing-leg reaction pad 626 and trailing-leg support 628 on opposite sides of the rail 700.

Figure 19 depicts an apparatus 810 which is a development of the apparatus of Figures 14 to 18 in that rail 800, instead of being straight, forms a gentle curve, higher at its forward and rearward extremes than in its middle. This assists in providing a natural action as the upper part of the trailing leg swings in use.

Figure 20 depicts a further apparatus 910 embodying certain aspects of the present invention. In the embodiments described above the user stands upright. By contrast, in use of the apparatus 910 the user 912 is intended to be prone – specifically, the user lies on one side. Thus in Figure 20, the plane of the paper is the plane of the floor surface on which the user 912 lies. In the illustrated example the user lies on his/her right-hand side and the right leg, nearest the floor is the leading leg 924. The left leg, furthest from the floor, is the trailing leg 922. But to exercise the opposite side of the body, the user can move onto his/her left-hand side, after which the left leg leads and the right leg trails.

As in previous embodiments the apparatus 910 provides:

- a trailing-leg reaction pad 926 configured to engage a front part of the trailing leg 922 at or above the knee, to react a forward force exerted by the trailing leg 922;

- a leading-leg reaction pad 930 configured to engage a rear part of the leading leg 924 at or below the knee, to react a rearward force exerted by the leading leg 924;

- a trailing-leg support 928 comprising an arm which is seen in the drawing and a cross beam which is not, the cross beam engaging the front of the lower part of the trailing leg 924 to maintain the leg in a state of flexion; and

- an arrangement, taking the form of a handle 982 in this particular embodiment, for reacting a rearward force exerted by the leading arm 984 (the leading arm being on the same side of the body as the trailing leg).

In this apparatus 910, a simple structure mounts and couples these parts. This structure comprises a first arm 1010 which carries the trailing-leg reaction pad 926 and which is coupled through a hub 1012 to a second arm 1014 which carries the leading-leg reaction pad 930. The hub permits some rotational movement of the first arm 1010 relative to the second arm 1014, this movement being limited by a force sensor 1016 which thus represents the muscular effort exerted by the legs. The handle 982 if formed on a limb 1018 projecting from the hub 1012.

This embodiment of the invention is especially simple and compact in its construction and may be well suited to domestic users.

Note that in contrast to certain existing pieces of exercise equipment which provide a symmetrical action, where first one leg leads and then the other, the present invention in all its aspects and embodiments provides an action which is asymmetric. The leading leg remains the leading leg throughout the exercise, and although the trailing leg may in some instances be moved, it plays the role of trailing leg throughout (until the user dismounts and swaps legs). The relative positions of the reaction pads and supports are maintained suitably throughout the exercise.

In all its embodiments, the present invention provides a range of possible functions and benefits. It can be used for testing, to assess baseline fitness and changes of fitness, e.g. in the course of an exercise regime. It can benefit elite athletes, especially but not exclusively those whose sports involve running, in optimising their performance, but it may be used by non-athletes. It may be used in dedicated clinics or gymnasia, or may be offered in a form well suited to home use. The invention may be used in both planning and implementing therapy. For example it may be used in the assessment and subsequent treatment of running-related injury, initially to assess the extent of a user's impairment and then to provide rehabilitative exercise targeted at relevant musculature.

It is believed that the invention may be beneficial in therapy provided to lower-leg amputees. The mass of a lower-leg prosthesis is typically smaller than that of the original limb. Users having a single prosthesis can suffer from asymmetric musculature development as a result, which can result in problems with the spine. Apparatus embodying the present invention can be used both to test for such asymmetric development and, through an appropriate exercise regime, to correct it.

The aforegoing embodiments are presented by way of example and not of limitation.

CLAIMS

1. An apparatus for fitness testing or exercise which has a front and a rear and which is configured to engage a forwardly-facing user in a posture in which one leg trails and the other leg leads, the apparatus comprising a structure which supports:

a rearwardly-facing trailing-leg reaction pad arranged to engage a front part of the user's trailing leg in a region at or above the knee;

an upwardly-facing trailing-leg support disposed lower than the trailing-leg reaction pad and disposed or extending rearward of the trailing-leg reaction pad to support the trailing leg below the knee, thereby maintaining the knee of the trailing leg in a state of flexion; and

a forwardly-facing leading-leg reaction pad arranged forward of the trailing-leg reaction pad to engage a rear part of the user's leading leg at or below the knee;

so that the user is able to exert a forward force upon the trailing-leg reaction pad using the trailing leg and a rearward force on the leading-leg reaction pad using the leading leg.

2. An apparatus as claimed in claim 1 in which the trailing-leg reaction pad is mounted through a force-measurement device sensitive to force applied to the trailing-leg reaction pad.

3. An apparatus as claimed in claim 1 or claim 2 in which the leading-leg reaction pad is mounted through a force-measurement device sensitive to force applied to the leading-leg reaction pad.

4. An apparatus as claimed in any preceding claim in which the leading-leg reaction pad is lower than the trailing-leg reaction pad.

5. An apparatus as claimed in any preceding claim, further comprising an upwardly-facing leading-foot support disposed below the leading-leg reaction pad to support the foot of the user's leading leg whilst the leading leg is engaged with the leading-leg reaction pad.

6. An apparatus as claimed in claim 5 in which the leading-foot support is able to move along a fore-and-aft direction.

7. An apparatus as claimed in claim 50 or claim 6 in which the leading-foot support is carried on a pivoting arm enabling it to move along a fore-and-aft direction.

8. An apparatus as claimed in any preceding claim in which the leading-leg reaction pad and/or the trailing-leg reaction pad are pivotally mounted.

9. An apparatus as claimed in any preceding claim comprising left and right leading-leg reaction pads, the left leading-leg reaction pad being arranged to engage the user's left leg when the left leg leads, and the right leading-leg reaction pad being arranged to engage the user's right leg when the right leg leads.

10. An apparatus as claimed in claim 9 comprising only a single trailing-leg reaction pad arranged in a central vertical plane parallel to the fore-and-aft direction and lying between the left and right leading-leg reaction pads.

11. An apparatus as claimed in any preceding claim further comprising an arrangement for engaging with a leading arm of the user on the opposite side of the user's body from the leading leg and for reacting a rearwardly-directed force exerted by the leading arm.

12. An apparatus as claimed in any preceding claim in which the arrangement for engaging with a leading arm of the user comprises a handle graspable with a hand of the leading arm.

13. An apparatus as claimed in claim 11 in which the arrangement for engaging with a leading arm of the user comprises a forwardly-facing reaction pad for engaging the leading arm above its elbow.

14. An apparatus as claimed in claim 11 in which the arrangement for engaging with a leading arm of the user comprises a force-measurement device sensitive to force applied by the leading arm.

15. An apparatus as claimed in any preceding claim in which height of the trailing-leg reaction pad is adjustable.

16. An apparatus as claimed in any preceding claim in which height of the leading-leg reaction pad is adjustable.

17. An apparatus as claimed in any preceding claim in which separation of the leading-leg reaction pad from the trailing-leg reaction pad along a fore-and-aft direction is adjustable.

18. An apparatus as claimed in any preceding claim in which the leading-leg reaction pad is mounted on a front upright column and the trailing-leg reaction pad and the trailing-leg support are mounted on a rear upright column, and wherein one of the columns is movable fore-and-aft relative to the other of the columns.

19. An apparatus as claimed in claim 18 in which the arrangement for engaging with a leading arm of the user is mounted on the front upright column, above the leading-leg reaction pad.

20. An apparatus as claimed in any preceding claim in which the trailing-leg reaction pad is reciprocally movable along a fore-and-aft path and is coupled to a loading mechanism which exerts a rearwardly-

acting resistance force on the trailing-leg reaction pad, so that the user is able to exercise by moving the trailing-leg reaction pad forwards against the resistance force using the trailing leg.

21. An apparatus as claimed in claim 20 in which the trailing-leg reaction pad is mounted for movement along a rail extending in a fore-and-aft direction.

22. An apparatus as claimed in claim 20 in which the rail is curved, being lower in its centre than at its ends.

23. An apparatus as claimed in claim 20 in which the loading mechanism comprises a stack of weights which are able to be coupled to the trailing-leg reaction pad to provide the resistance force.

24. An exercise apparatus which has a front and a rear and which is configured to support a forwardly-facing user in a posture in which one leg trails and the other leg leads, the apparatus comprising a structure which supports:

a rearwardly-facing trailing-leg reaction pad which is arranged to engage a front part of the user's trailing leg in a region at or above the knee and which is mounted for reciprocal movement along a path extending in a fore-and-aft direction;

a forwardly-facing leading-leg reaction pad arranged forward of the trailing-leg reaction pad to engage a rear part of the user's leading leg at or below the knee; and

a loading mechanism which exerts a rearwardly-acting resistance force on the trailing-leg reaction pad,

so that the user is able to exercise by moving the trailing-leg reaction pad forwards against the resistance force using the trailing leg.

25. An apparatus as claimed in claim 24 in which the trailing-leg reaction pad is movably mounted on a rail extending in the fore-and-aft direction.

Intellectual Property Office

Application No:	GB2300480.7	**Examiner:**	Daniel Cox
Claims searched:	1-23	**Date of search:**	27 June 2023

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
A	-	US4247098 A BRENTHAM, See figure 3 in particular
A	-	TWM540670 U CHEN, See the figures

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^{X} :

Worldwide search of patent documents classified in the following areas of the IPC

A63B

The following online and other databases have been used in the preparation of this search report

WPI, EPODOC

International Classification:

Subclass	Subgroup	Valid From
A63B	0023/04	01/01/2006
A63B	0021/00	01/01/2006
A63B	0021/002	01/01/2006
A63B	0021/062	01/01/2006
A63B	0024/00	01/01/2006

Intellectual Property Office

Application No: GB2300480.7 **Examiner:** Daniel Cox

Claims searched: 24 & 25 **Date of search:** 15 January 2024

Patents Act 1977
Further Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
A	-	US4247098 A BRENTHAM, See the figures
A	-	WO2009/104206 A1 PARISE, See the figures

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
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Field of Search:

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International Classification:

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A63B	0023/04	01/01/2006
A63B	0021/00	01/01/2006
A63B	0021/002	01/01/2006
A63B	0021/062	01/01/2006
A63B	0024/00	01/01/2006