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Tong et al.

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(54) **MULTIPLE JOINT LINKAGE DEVICE**

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(51) **Int. Cl.**
A61H 1/02 (2006.01)

(52) **U.S. Cl.** **601/5**; 601/33

(58) **Field of Classification Search** 601/5, 601/27, 31, 32, 33–36, 40; 482/44–46
See application file for complete search history.

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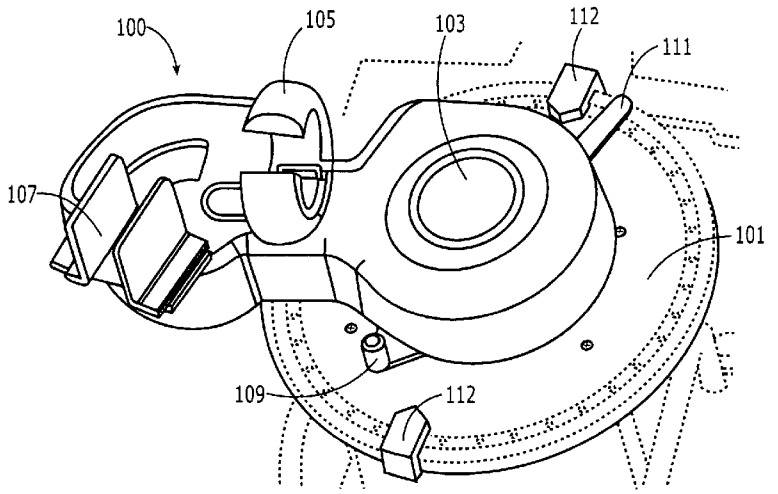
(57) **ABSTRACT**

The present invention relates to devices and methods for a joint linkage device suitable for training multi-joints in a single limb. The joint linkage device is capable of rotation at a proximal end and a distal end. The device includes a proximal end having an upper plate, a middle plate, and a lower plate, a distal plate, a side bar, a main bar, a switch mechanism, and an extended bar. In use, a torque from a motor is applied to the upper plate to provide a user with an assistance torque, a resistance torque, or a assistance/resistance torque.

17 Claims, 9 Drawing Sheets



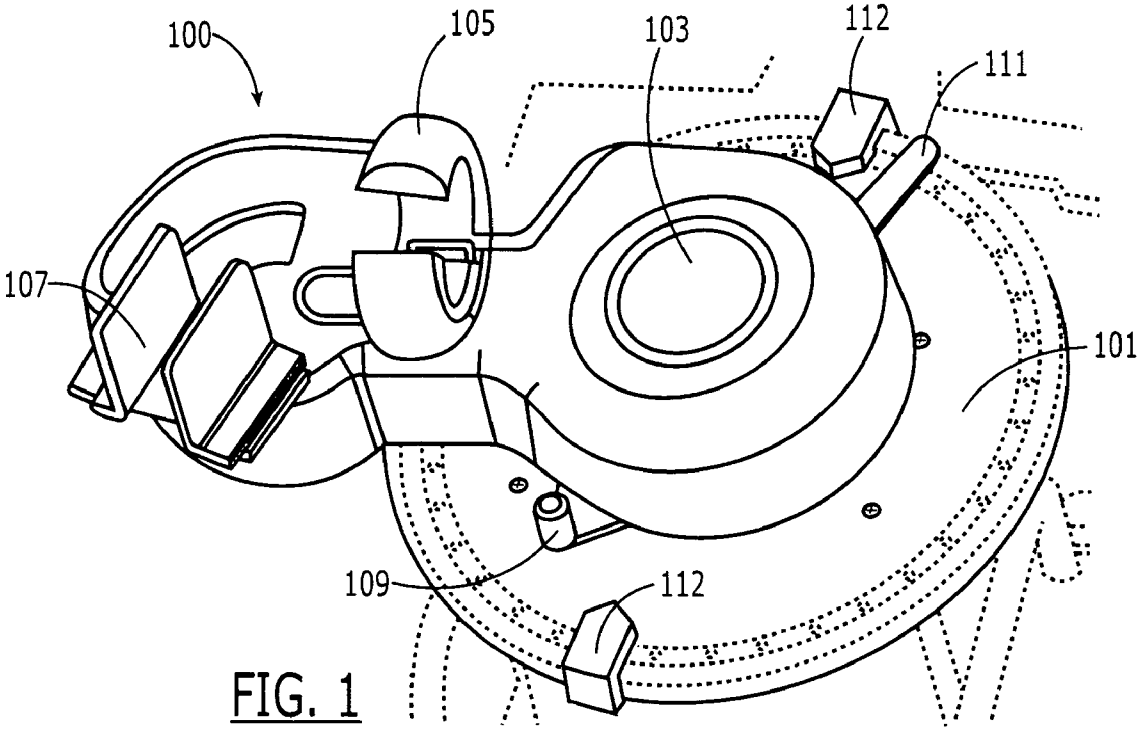


FIG. 1

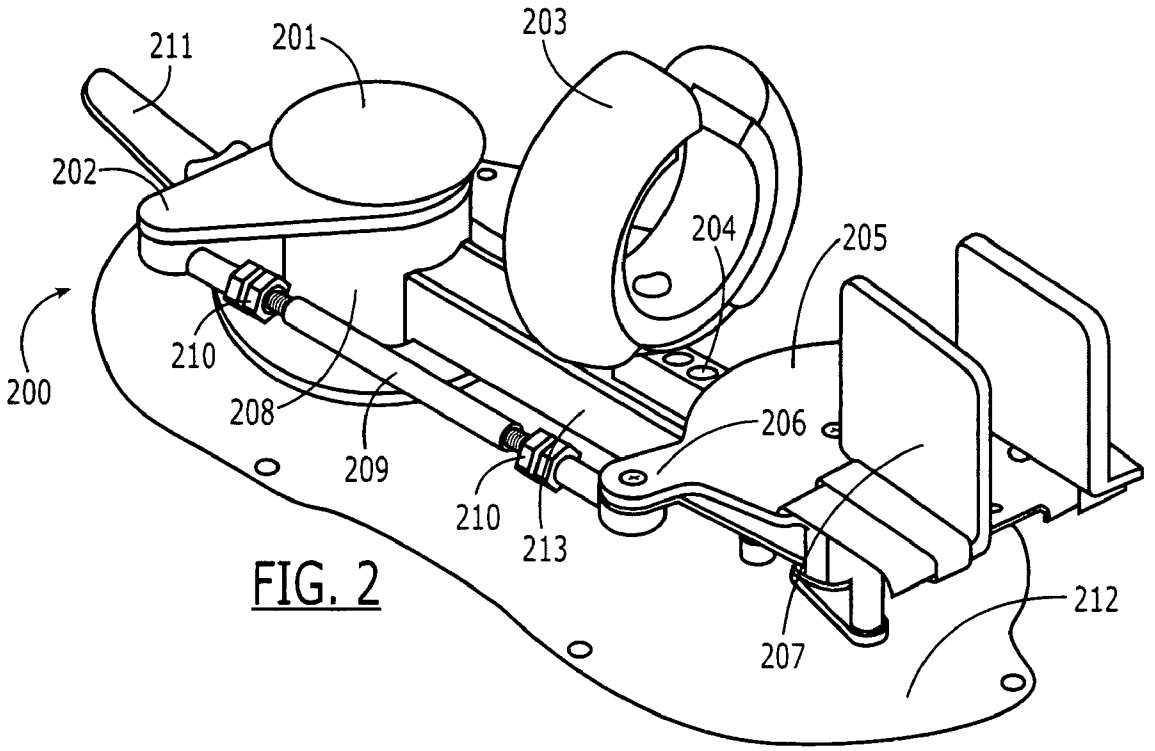


FIG. 2

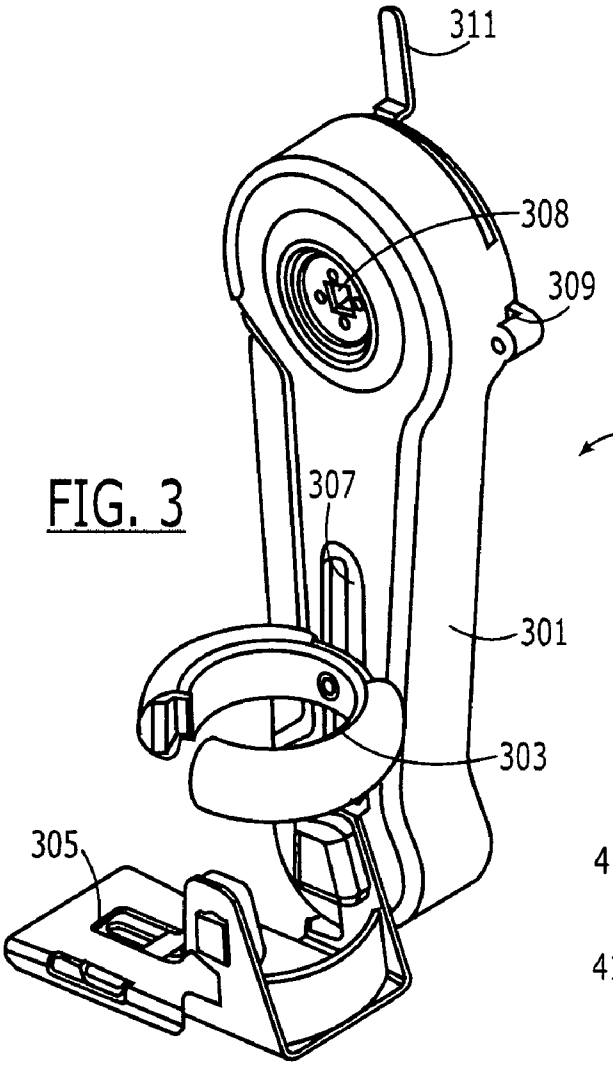

311
308
309
300
307
301
303
305

FIG. 3

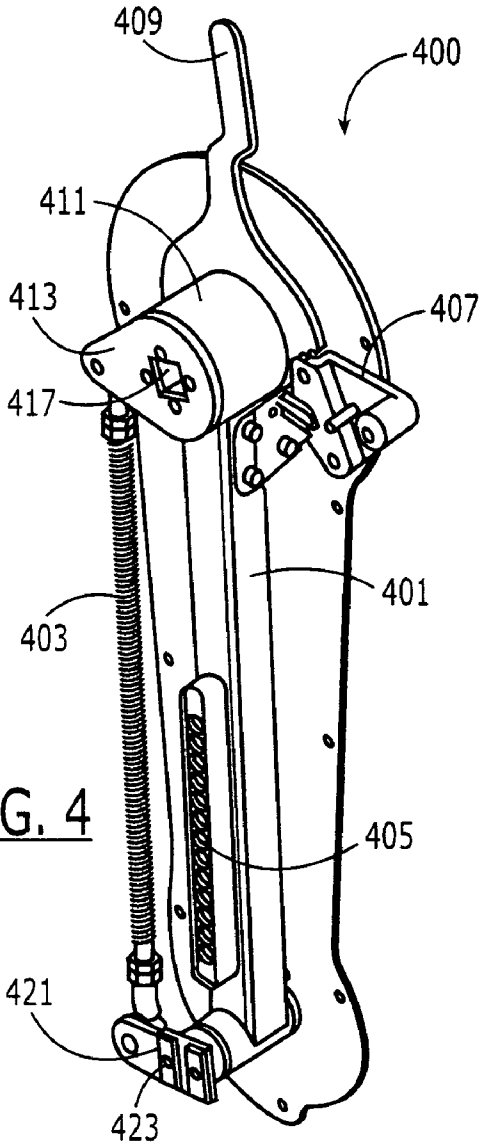

409
400
411
413
407
417
401
403
405
421
423

FIG. 4

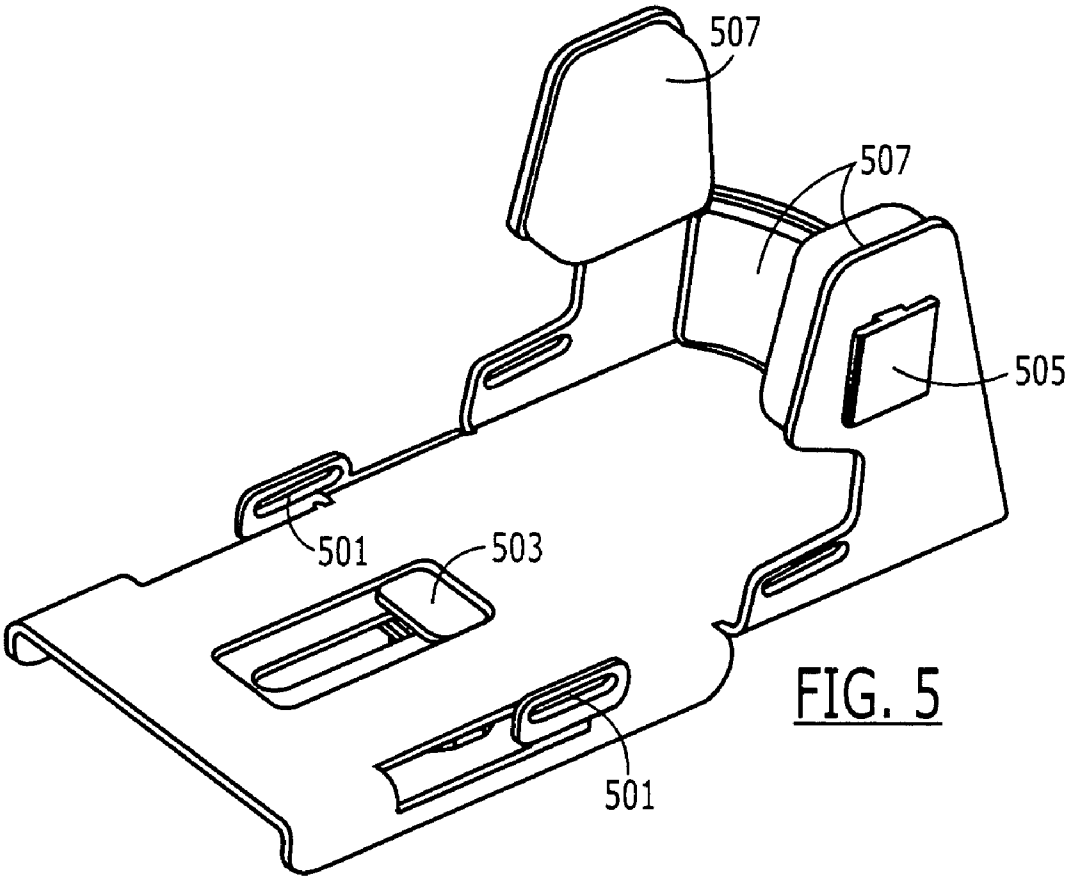


FIG. 5

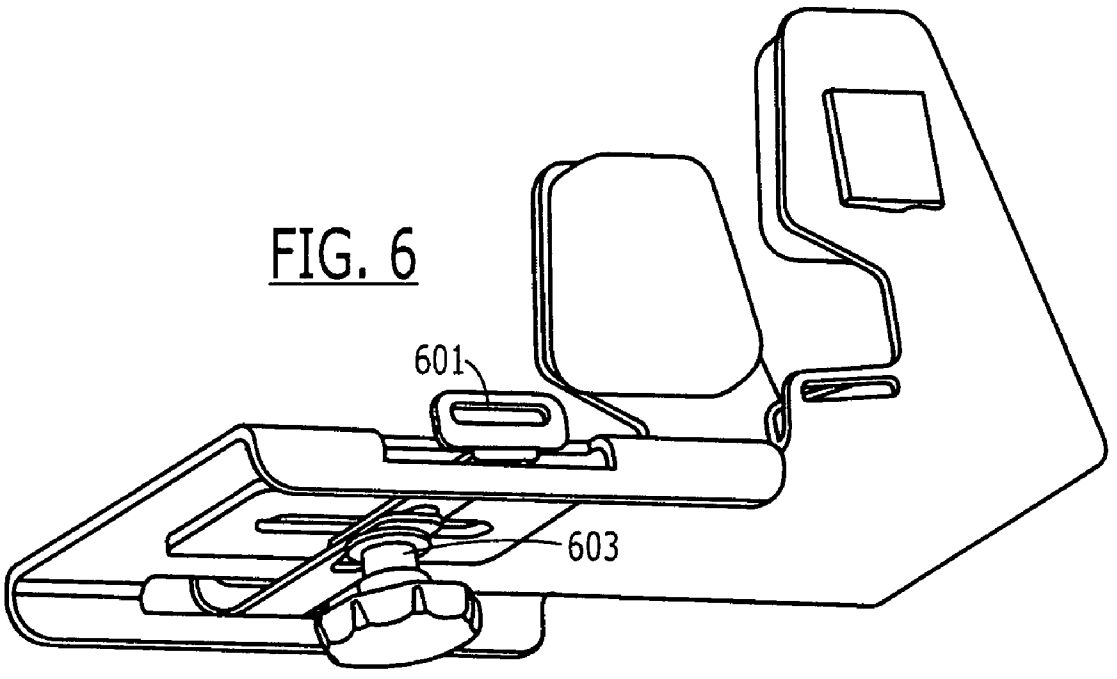


FIG. 6

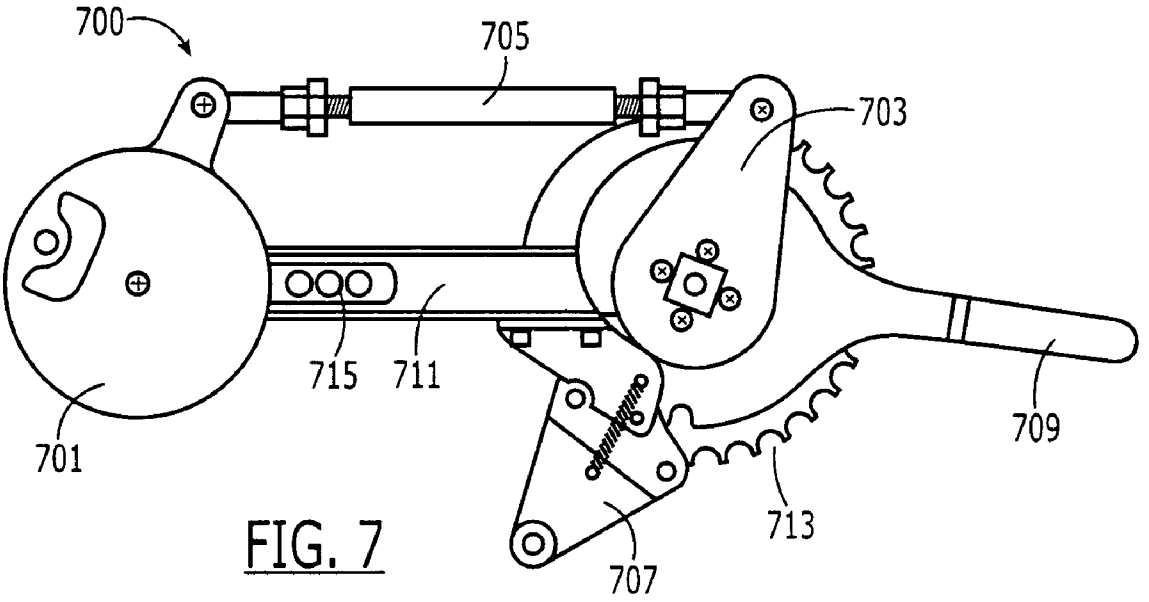


FIG. 7

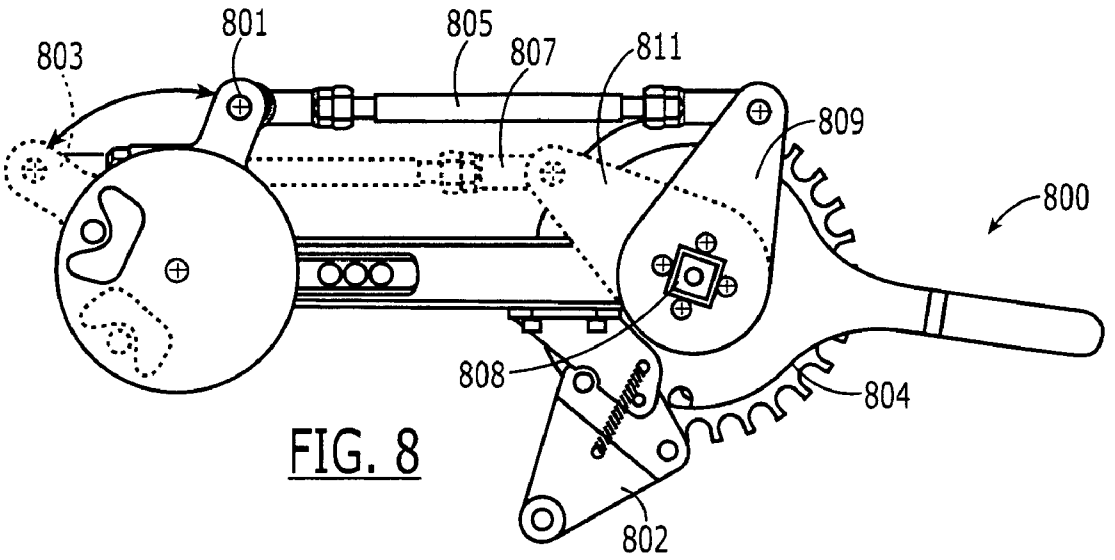

803
801
805
807
811
809
800
808
804
802

FIG. 8

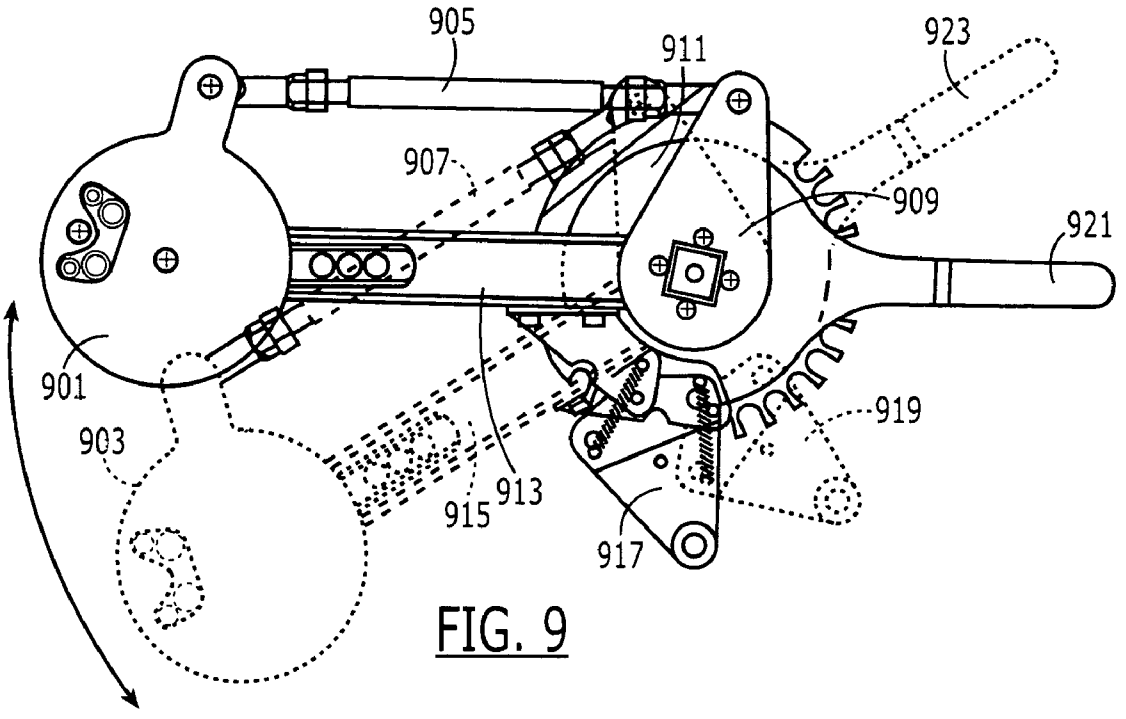

905
911
923
907
909
921
901
903
919
915
913
917

FIG. 9

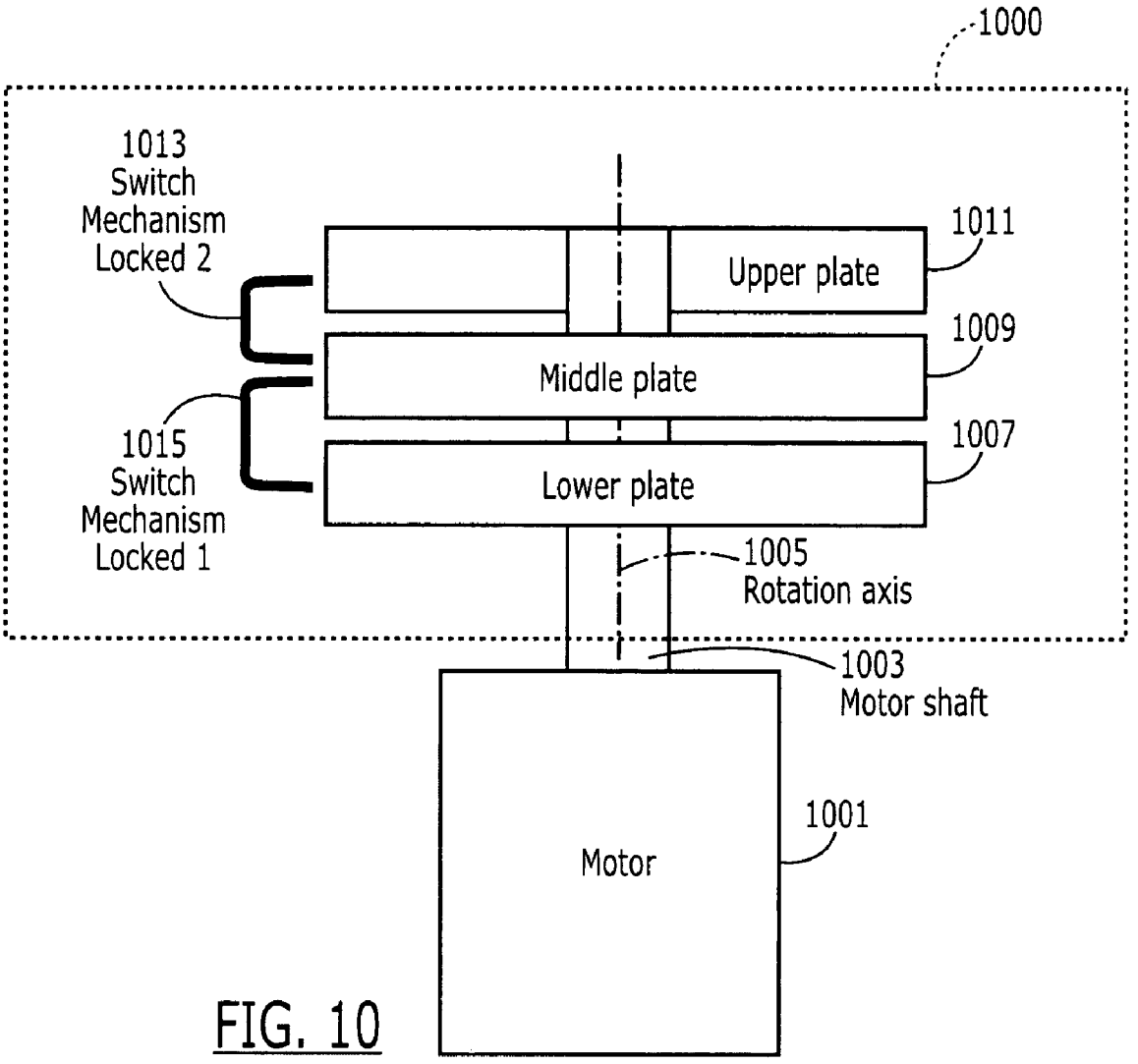

1000
1013
Switch
Mechanism
Locked 2
1011
Upper plate
1009
Middle plate
1015
Switch
Mechanism
Locked 1
1007
Lower plate
1005
Rotation axis
1003
Motor shaft
1001
Motor

FIG. 10

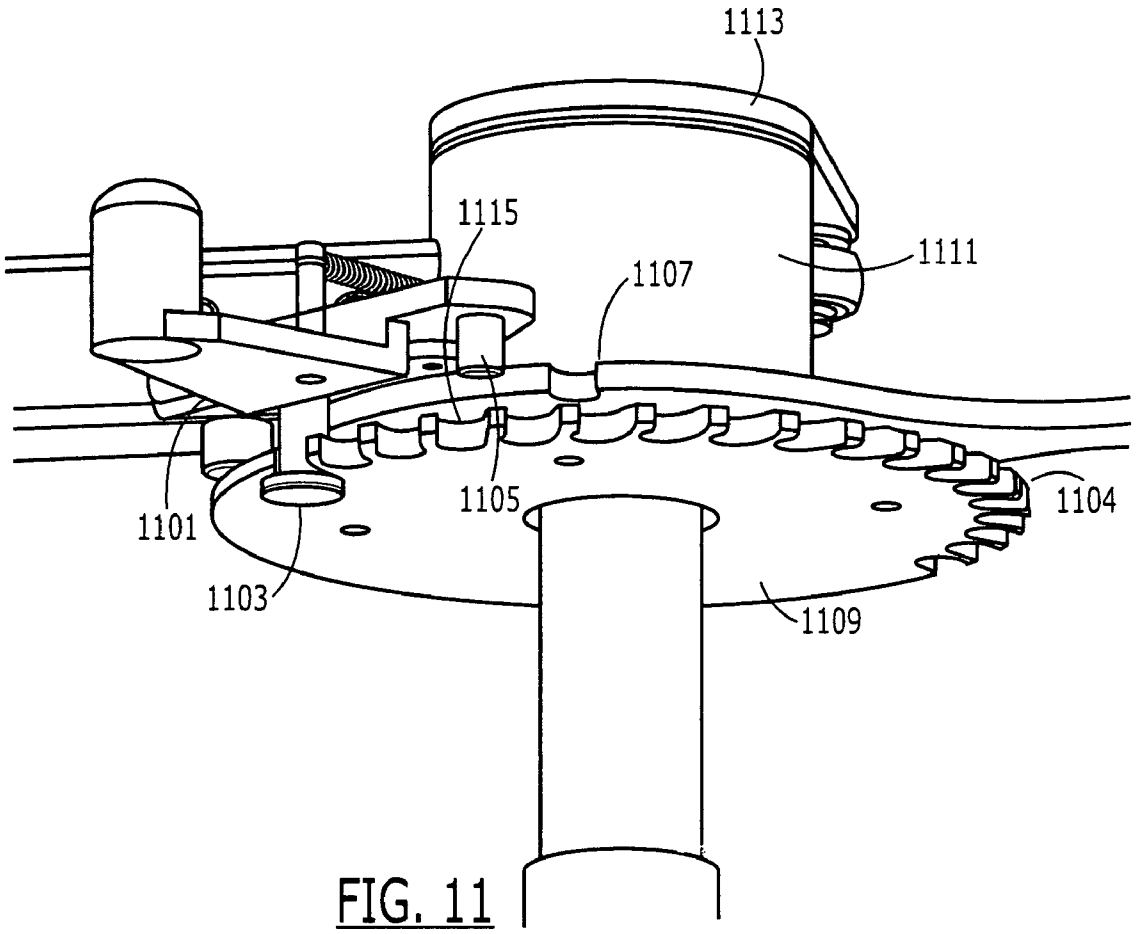


FIG. 11

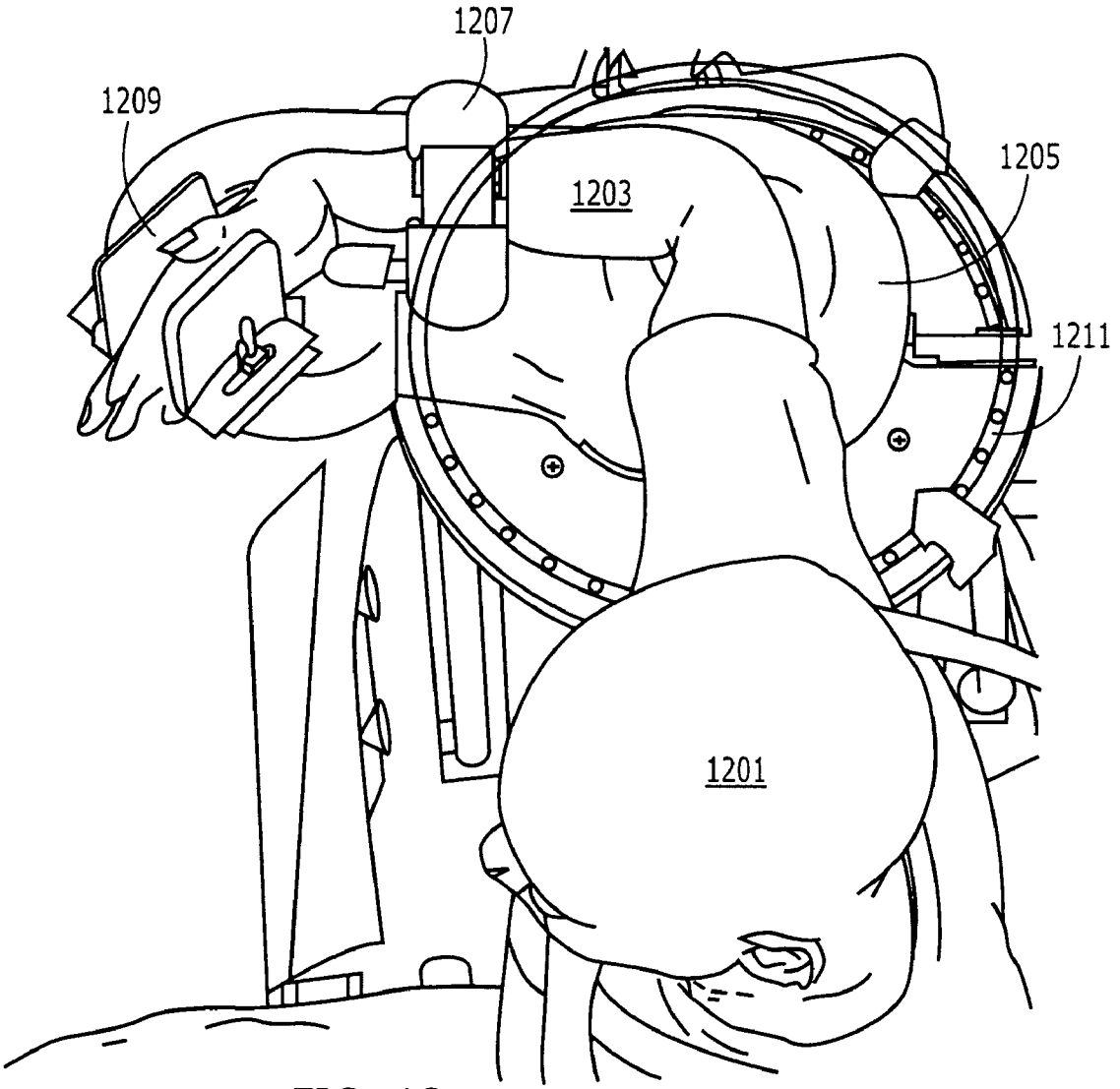


FIG. 12

MULTIPLE JOINT LINKAGE DEVICE

BACKGROUND

Massive trauma to a body, such as a stroke, head injury, or spinal cord injury, and even old age, can cause a person's motor skills in multiple muscle groups to be impaired and the person often losses the full range of motion in the limbs. Usually, such affected people under various forms of therapy attempt to regain the full range motion. In the present day, therapy machines are often utilized to retrain various limbs in movement.

However, the affected person often have more than one muscle group impaired, or on one limb, there may be several joints incapable of satisfactory movement following trauma. In such circumstances, when a therapy machine is used, multiple add-on modules are required in order to train different joints on one limb. For example, one module may be required for elbow joint rotation thus training the infraspinals and teres minor. Another module may be required for wrist joint rotation, thus training the supraspinals. The use of more than one module requires "switching out" or removing one module from a machine and replacing it with another. "Switching out" is time consuming, and if the impaired person is training alone, is almost impossible.

It is an object of the present invention to present devices and method to allow the training of multiple joints on a limb using one training module, and over the disadvantages of the prior art.

DESCRIPTION

The present invention proposes a joint linkage device capable of training more than one joint in a limb.

The present invention also proposes methods for multi-joint training in a single limb using a module of the present invention.

The present invention further proposes training more than one joint in a single limb by using a module containing distal and proximal plates, connected by bars capable of rotation, whereby both plates may rotate during alternate modes.

The present invention still further proposes devices and methods described herein to aid impaired persons and trainers from having to use more than one training module when training a limb.

These and other features, aspects, and advantages of the apparatus and methods of the present invention will become better understood from the following description, appended claims, and accompanying drawings where:

FIG. **1** is an embodiment of the joint linkage device of the present invention.

FIG. **2** is an embodiment of the internal components of the joint linkage device.

FIG. **3** is an embodiment of a lower extremity joint linkage device of the present invention.

FIG. **4** shows the internal components of the lower extremity joint linkage device.

FIG. **5** shows an embodiment of the foot rest device to be attached to the lower extremity joint linkage device (top side).

FIG. **6** shows the bottom side of foot rest device.

FIG. **7** shows the topside view of the internal components of the upper extremity joint linkage device.

FIG. **8** shows the method of rotation capability of the upper extremity joint, rotation being at the distal end.

FIG. **9** shows the method of training a proximal joint of a user, with rotation being at the proximal end.

FIG. **10** shows the method of movement when the switch mechanism of the invention is in locked **1** or locked **2**.

FIG. **11** provides a view of the switch mechanism and plates of the device.

FIG. **12** exhibits the user interacting with the device.

The following description of certain exemplary embodiment(s) is merely exemplary in nature and is in no way intended to limit the invention, its application, or uses. Throughout this description, the term "user" refers to human patients requiring neuro-muscular rehabilitation. The term "electronically operable" refers to systems generally employing micro-processors, resistors, capacitors, inductors, and sensors for extracting information from mechanical inputs and outputs via electrical activators to mechanical systems. The term "rotatably positioned" refers to a component capable of movement in the x, y, and/or z plane while being connected to another component.

Now, to FIGS. **1-12**, which, while presented individually, in total teach the present invention.

The present invention relates to a device and methods for rotating multiple joints of a limb using one joint linkage device. Through the device, users do not need to utilize more than one device when exercising multiple joints on a limb. The present invention improves upon prior art method of requiring multiple devices by using a newly developed linkage system to transfer the rotation axis from a proximal to a distal location, and vice versa. The device is suitable for being mounted on training or exercise equipment. In one embodiment, the device is mounted on a robotic system.

FIG. **1** shows an embodiment of the joint linkage device **100** of the present invention. The joint linkage device **100** includes an elbow rest **103**, an arm cuff **105**, a hand clasp **107**, a switch mechanism **109**, and an extended bar **111**. As shown, the device **100** is designed for being mounted on or attached to a surface **101**, for example a nautilus machine, a robotic system, and the like.

The elbow rest **103** is suitable for accepting an elbow of a user. The rest **103** can be made of a supple material to allow comfort when resting the elbow. The diameter of the rest **103** can be such that it can accommodate elbows of different sizes.

The arm cuff **105** is suitable for holding the forearm (and limb, in general) in place within the device. While the embodiment **100** shows the cuff **105** to be bracelet-like, different style arm cuffs may be used while not deviating from the invention, for example Velcro straps, square-shaped cuffs, etc. The cuff **105** should have an expandable means, such as a movable joint, for accommodating forearms of different sizes. As will be discussed later, the cuff **105** can be positioned along different areas of the device **100** to allow maximum comfort for the user.

A hand clasp **107** is used to maintain the limb in a particular position, as well as being instrumental in exercising the wrist joint. In use, the clasp **107** accommodates a hand between two plates, and then the plates are closed in until the hand is firmly held. The plates of the clasp **107** may be manually operated or electronically operable. In manual operation, the plates are moved together, and then secured into position with a screw-type means.

In being electronically operable, the plates are closed together in response to an electronic signal; a sensor can be used to indicate when enclosing should stop because the hand is firmly held. The clasp **107** should be covered with a material to make it suitable for skin contact, for example cotton, polyester, silk, padding, and the like.

A switch mechanism **109** is included for switching between joints during training. As will be discussed later, the switch mechanism **109** actuates a pawl for insertion into a

particular ratchet. The switch mechanism **109** may be manually operated or electronically operable. For manual operation, the switch mechanism **209** preferably possesses a knob or handle for actuation. In being electronically operable, the switch mechanism **209** may be wired or wirelessly connected to controller for receiving an electric signal. The switch mechanism **109** is preferably in a joint, allowing the mechanism **109** one translational degree of freedom.

The overall movement (rotation) of the device **100** is range limited by an extended bar **111** and stoppage blocks **112** positioned on the surface **101**. The blocks **112** can be positioned to provide a range of movement from 10° to 270° along the surface circumference. The blocks **112** are can be made of a scratch resistant material, such as rubber or another polymer, or a metal.

FIG. **2** is an embodiment of the internal components of the joint linkage device **200**. The internal components include but are not limited to, upper plate **201**, distal plate **205**, main bar **213**, and side bar **209**.

The upper plate **201** serves a torque deliverer, capable of transmitting a torque from a motor to the distal plate **205**. The upper plate **201** preferably possesses an extended portion **202** for connecting with the side bar **209** and a base for connecting to the device's chassis **212**. As will be discussed later, the side bar **209**, while connected to the extended portion **202**, is allowed rotation. The upper plate **201** also provides the underlying support to a user's elbow. The upper plate **201** sits on a middle plate **208**.

As stated previously, a side bar **209** is one means of attachment between the upper plate **201** and the distal plate **205**. The side bar **209** can be made of a metal, such as stainless steel, or a polymer such as a hard plastic. The side bar **209** can have a male end for connecting to a female end, such female end being the extended portion of the upper plate **201** and the distal plate **205**. In a preferred embodiment, the side bar **209** possesses helical grooves or thread-formed ends on either side for fastening a nut **210** attached to the plates **201**/**205**. In such an embodiment, the operation of the device **200**, namely the transmitting of torque from the upper plate **201** to the distal plate **205**, can be enhanced or minimized by the screwing or unscrewing the side bar **209** from either nut **210**.

The distal plate **205** is suitable for providing underlying support for a distal portion of a user's limb. The distal plate **205** preferably includes an extended portion **206** for connecting to the side bar **209** and a base (not shown) for attachment to the chassis **212**. The distal plate **205** contains means for accepting the hand clasp **207**, such as adaptor holes (not shown).

The upper plate **201** and the distal plate **205** are principally connected by a rotatably positioned main bar **213**. The main bar **213** also provides support for the device **200**, and acts as a support for the limb's middle section, such as forearm. The main bar **213** further includes positioning means **204**, such as holes, allowing the arm cuff **203** to be adjusted. As will be discussed later, the main bar **213** possesses components allowing it to be rotated during operation of the device **200**.

As stated earlier, the device may be manually or electronically operable. In being manually operable, adjustments such as the side bar **209**, or the position of the arm cuff **203**, can be made by a user or operator physically interacting with the device **200**. In being electronically operable, adjustments can be made via a controller wired or wirelessly connected to the device **200**. In such an embodiment, the device should contain electronic components including but not limited to resistors, capacitors, and inductors, as is known in the art.

FIGS. **3** and **4** show the external and internal components of lower extremity device of the present invention.

FIG. **3** shows the external component of an embodiment of a lower extremity joint linkage device **300**. The device **300** includes a body **301**, a shank cuff **303**, a foot rest **305**, a knee brace **308**, cuff adjustment means **307**, a switch mechanism **309**, and an extended bar **311**.

The body **301**, as in the lower extremity joint linkage device, can be a light weight metal or a polymer/plastic material. Preferably, the body **301** is plastic.

The shank cuff **303** can be a bracelet design with a closeable clasp on the cuff. In other embodiments, the shank cuff **303** can be any attachment device suitable for holding the leg shank in position, for example Velcro strap, chain, etc. The position of the shank cuff **303** can be adjusted by the cuff adjustment means **307**, such as various holes into which the shank cuff **303** can be inserted into. The cuff adjustment means **307** can extend the full length of the device **300**.

The foot rest **305** is used for resting the foot of the user. The foot rest is also capable of providing training to the ankle joint of the user. The foot rest **305** is adjustable to accept a variety of foot sizes.

A switch mechanism **309** is included to allow toggling between training the knee joint, ankle joint, or hip joint of the user. The switch mechanism **309** activates a pawl for insertion into a particular ratchet. Like the upper extremity device, the switch mechanism **309** may be manually or electronically operable. Operation includes the switch **309** operating in a joint.

A knee brace **308** is used for providing support to the outside of the user's knee. This is to ensure that, when being trained, the user's limb is focused on vertical movement as opposed to horizontal movement.

The range of movement of the device is limited by an extended bar **311**. The extended bar **311** limits movement by contacting blocks positioned on a surface. The blocks can be from 10° to 270° apart.

FIG. **4** shows the internal components of an embodiment of a lower extremity device **400** of the present invention.

The components of the device **400** includes an upper plate **413**, a middle plate **411**, and a distal plate **421**, wherein the upper plate **413** and distal plate **421** are connected with a side bar **403** and main bar **401**.

The upper plate **413** is used for accepting a shaft from a motor device, such device being used to aid during training. The upper plate **413** includes an extended portion for contacting with the side bar **403**, and a hole **415** to accept the shaft.

The side bar **403** extends from the upper plate **413** to the distal plate **421**. The side bar **403** can be made of a metal, such as stainless steel, or a polymer such as hard plastic. The side bar **403** can have a male end for connecting to female ends such as a nut **417**, such female ends being on both the upper plate **413** and the distal plate **421**.

The distal plate **421** is positioned adjacent to an adaptor **423** for accepting the foot rest (not shown). The distal plate **421** connects to the upper plate **413**, and is actuated by the upper plate **413** when torque is applied by a motor. The adaptor **423** is activated when the distal plate **421** is rotated, leading to rotation of the foot rest.

A main bar **401** is rotatably positioned between the middle plate **411** and the foot rest adapter **423**. The main bar **401** is allowed to rotate through the use of ball bearings. The main bar **401** further includes a shank cuff adjustment means **405**, such as holes, for positioning the shank cuff.

As stated previously, the device **400** includes a switch mechanism **407** and extended bar **409**.

FIGS. **5** and **6** show the foot rest to be used with a lower extremity device of the present invention.

FIG. **5** exhibits a foot rest embodiment **500** having strap holders **501**, an adjustable knob **503**, an adapter connector **505** to connect to the joint linkage device, and pods **507** for accommodating a user's foot.

FIG. **6** shows the bottom side of the foot rest, including the strap holders **601** and the adjustable knob **603**.

FIG. **7** is a top side view of an upper extremity joint linkage device, including but not limited to a distal plate **701**, an upper plate **703**, a side bar **705**, a switch mechanism **707**, a lower plate with ratchets **713**, an extended bar **709**, a main bar **711**, and arm cuff adjustment means **715**. The lower plate with ratchets **713** is suitable for accepting the switching mechanism **707** and locking it in place via the pawl (not shown). Holes on the lower plate **713** can accept a connector on the switch mechanism **707** to allow different proximal joint angles during the rotation training on the distal joint. In one embodiment, the holes are 10 degrees apart, which means the joint angle can adjust by 10 degrees each time.

FIG. **8** is a method of rotating a distal plate of a joint linkage device.

In training, torque is applied to the device **800** by a motor attached to the upper plate **809** specifically through a hole in the upper plate **808**. Firstly, the switch mechanism **802** is locked in place along the lower plate with ratchets **804**. As stated, the switch mechanism **802** has a pawl for interacting with the lower plate. The upper plate in a first position **809** is moved by the user, aided or resisted by a torque rotating the device **800**. Movement of the upper plate to a second position **811** causes the side bar in a first position **805** to move to a second position **807**. The movement of the side bar causes the distal plate to move from a first position **801** to a second position **803**. In this embodiment, when the switch mechanism **802** is locked thusly, the rotation of the distal plate **801**/**803** allows a distal joint of the user, for example the wrist joint or ankle joint, to be rotated.

FIG. **9** is a method of rotating a proximal plate of a joint linkage device. In this method, the switch mechanism is locked in a position such that the distal plate does not rotate, but the main bar is allowed to rotate.

Firstly, the switch mechanism is locked the upper plate and middle plate. In use, a torque is applied to the upper plate via a motor. Upon application, the upper plate moves from a first position **909** to a second position **911**. The side bar moves from a first position **905** to a second position **907**. Simultaneously, the main bar is rotates along the middle plate (not shown), from a first **913** to a second position **915**. The distal plate does not rotate position in response to the main bar, from a first position **901** to a second position **903**.

FIG. **10** exhibits the means by which the joint linkage device is capable of rotating both a distal and a proximal plate.

As stated earlier a motor **1001** provides torque to the training device **1000** via a motor shaft **1003**. The motor shaft connects directly to an upper plate of the device **1000**. The upper plate **1011** is connected to the distal plate (not shown) to generate distal joint rotation if the middle plate **1009** is not locked with the upper plate **1011**. The lower plate **1007** is permanently locked in place.

In use, if the switch mechanism is locked in position **1** **1015**, the middle plate **1009** and lower plate **1007** are locked together. The upper plate **1011** then rotates with the motor **1001**, and the middle plate **1009** and the lower plate **1007** are locked in position. The device is now able to rotate a distal plate.

In another method, the switch mechanism is locked in position **2** **1013**. This position locks the middle plate **1009** with the upper plate **1011**. The middle **1009** and upper **1011** plates are able to rotate together with the motor, while the lower plate **1007** is fixed. Such a method is able to generate rotation in a proximal plate of the device.

FIG. **11** is an embodiment of the switch mechanism and plates of the training device. The switching mechanism **1101**, through its handle, is able to contact one of two positions, specifically a first hole **1103** or a second hole **1107**. An additional pawl **1105** on the switch mechanism **1101** allows the second lock **1107** to be contacted. In a first hole **1103**, the lower plate **1109** via ratchets **1115**, is locked along with the middle plate **1111**. In the second hole **1107**, the middle plate **1111** is locked with the upper plate **1113**.

FIG. **12** is an embodiment of a user interacting with the present joint linkage device.

The user's **1201** limb **1203** is positioned through the arm cuff **1207** of the device **1205**. The user's hand **1209** is set into the hand clasps. As shown, the device **1205** is locked into a position where the distal plate is allowed rotate, thus allowing the wrist joint of the user **1201** to rotate.

The device **1205** is mounted on a robotic system **1211**.

Having described embodiments of the present system with reference to the accompanying drawings, it is to be understood that the present system is not limited to the precise embodiments, and that various changes and modifications may be effected therein by one having ordinary skill in the art without departing from the scope or spirit as defined in the appended claims.

In interpreting the appended claims, it should be understood that:

a) the word "comprising" does not exclude the presence of other elements or acts than those listed in the given claim;

b) the word "a" or "an" preceding an element does not exclude the presence of a plurality of such elements;

c) any reference signs in the claims do not limit their scope;

d) any of the disclosed devices or portions thereof may be combined together or separated into further portions unless specifically stated otherwise; and

e) no specific sequence of acts or steps is intended to be required unless specifically indicated.

The invention claimed is:

1. A joint linkage device for training multiple joints in a limb, comprising

an upper plate having an extended portion;

a middle plate positioned underneath said upper plate;

a lower plate positioned underneath said middle plate having a switch mechanism attached thereto;

a distal plate having an extended portion;

a side bar rotatably positioned between both of said extended portions;

a main arm rotatably positioned between said middle plate and the base of said distal plate;

a cuff;

a clasp selected from group consisting of a foot rest and a hand clasp;

and

extended bar for contacting stoppage blocks,

wherein said lower plate includes ratchets on its perimeter for contacting a pawl actuated by said switch mechanism.

2. The joint linkage device in claim **1**, further comprising a cuff adjustment means.

3. The joint linkage device in claim **1**, further comprising an adaptor adjacent to said distal plate.

4. The joint linkage device in claim **3**, wherein said clasp is attached to said adaptor.

5. The joint linkage device in claim **1**, wherein said side bar comprises threaded ends on both ends.

6. The joint linkage device in claim 5, wherein said extended portions of said upper plate and distal plate have female ends for accepting said threaded ends of said side bar.

7. The joint linkage device in claim 1, wherein said clasp is rotatably positioned on said distal plate.

8. The joint linkage device in claim 1, wherein said upper plate further comprises a hole to accept a motor shaft.

9. The joint linkage device in claim 1, further comprising electronic components for making the device electronically operable.

10. The joint linkage device in claim 1, further comprising a body.

11. A method of rotating a distal plate of a joint linkage device, comprising the steps of

locking a middle plate and a lower plate;

applying a torque to an upper plate;

rotating said upper plate from a first position to a second position, while simultaneously

rotating a side bar from a first position to a second position;

and

rotating said distal plate from a first position to a second position.

12. The method of rotating a distal plate in claim 11, wherein locking said middle plate and said lower plate occurs by actuating a switch mechanism to contact a pawl with ratchets on said lower plate.

13. The method of rotating a distal plate in claim 11, wherein applying a torque is selected from the group consisting of an assistance torque, a resistance torque, and a assistance/resistance torque.

14. The method of rotating a distal plate of a joint linkage device in claim 11 further comprising the step of

leaving stationary main bar between a proximal part and distal part of said joint linkage device.

15. A method of rotating a proximal plate of a joint linkage device comprising the steps of:

locking an upper plate and a middle plate;

applying a torque to said upper plate;

rotating said upper plate from a first position to a second position;

rotating a side bar from a first position to a second position;

rotating a main bar from a first position to a second position;

and

moving a distal plate from a first position to a second position,

wherein said distal plate does not rotate.

16. The method of rotating a proximal plate of a joint linkage device in claim 15, wherein applying a torque is selected from the group consisting of an assistance torque, a resistance torque, and a assistance/resistance torque.

17. The method of rotating a proximal plate of a joint linkage device in claim 16, wherein locking said upper plate and middle plate occurs by actuating a switch mechanism.

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