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(54) **Title:** MODULAR TENDON-ACTUATED EXOSKELETON FOR GAIT TRAINING

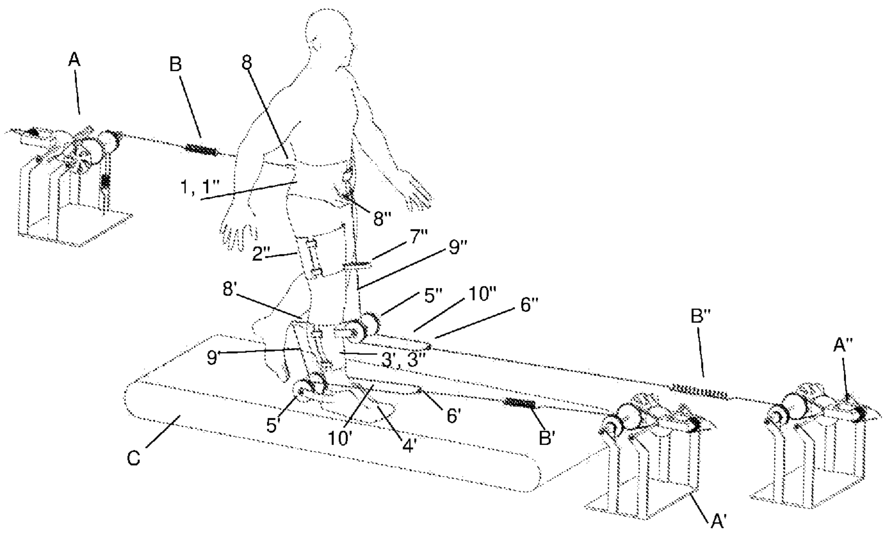

Fig. 1

(57) **Abstract:** The subject of the invention is a modular tendon-actuated exoskeleton for gait training. The modular tendon-actuated exoskeleton allows externally imposed torques to be generated in the leg joints (hip, knee and ankle) of a person walking on a treadmill. The modular tendon-actuated exoskeleton of the invention consists of one or more support modules and a compensation system, where the support modules and the compensation system are connected via connecting elements (B, B', B") to braking systems (A, A', A").

[Continued on next page]

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MODULAR TENDON-ACTUATED EXOSKELETON FOR GAIT TRAINING

The subject of the invention is a modular tendon-actuated exoskeleton for gait training. The modular tendon-actuated exoskeleton allows externally imposed torques to be generated in the leg joints (hip, knee and ankle) of a person walking on a treadmill.

The use of rehabilitation robots is part of the established methods for gait training in people who have suffered a neurological disease or injury (e.g. stroke). Robots in the form of exoskeletons are used in the early phase of gait rehabilitation and are an effective tool for gait training. Exoskeletons are usually formed of rigid segments. The segments and motors of the exoskeleton, which are attached to the leg segments, represent additional mechanical impedance to the person's movement by their weight. The structure of the exoskeleton limits the movement of the leg. Typically, exoskeletons provide controlled guidance of the hip and knee, but ankle guidance is either absent or limited to dorsiflexion of the foot during the swing phase, which prevents a person from striking the ground with his/her toes. With modern exoskeletons, only generic training is possible that does not focus on a specific sub-phase of the gait cycle (e.g. push-off training, swing training) or the function of a specific muscle group (e.g. strengthening of the knee flexors).

The devices known so far, which train walking by forcing movement mostly require servo-motor drives, and in rare cases hydraulic and pneumatic actuators. Due to the rich dynamics of gait, the drives need to achieve correspondingly high force/torque ratings. Control of devices with such drives requires the use of closed-loop impedance/admittance control schemes. Such devices are therefore expensive and complex, and thus challenging from a risk management point of view. To ensure safety, such devices therefore need supporting safety systems.

Certain tasks of modern exoskeletons can be solved with different devices. Stepping training can be carried out with robots that are only in contact with person's feet. These robots are less restrictive of the leg movement but do not allow direct control of the kinematics in the leg joints. For certain tasks conventional exoskeletons can be replaced by soft exo-suits, which, due to their light and soft segments, are less restrictive of the leg movement and do not add much mechanical inertia to the leg movement. The disadvantage of soft exoskeletons lies in particular in the fact that they only achieve small torques.

Given the prior art, there is a need for a more effective, cheaper and safer technical solution to the rehabilitation of stepping with exoskeletons.

The proposed modular tendon-actuated exoskeleton allows the generation of torques in the leg joints (hip, knee and ankle). The main mechanical feature of the proposed device is the separation of the drive part of the device from a wearable orthosis. The person only bears the weight of a lightweight orthosis which is connected to the propulsion system by a tendon. The propulsion system follows the movement of the body segments so that the string is always stretched. The drive of the exoskeleton can be carried out using a servomotor or using an energy exchange system. The braking system allows the energy of the treadmill motion to be stored in the elastic energy of a spring, which is then used to exert forces or torques on the leg segments. The proposed solution is an upgraded form of the braking system which, by adding eddy-current braking, also allows energy dissipation and slowing down of the motion without a complete stop. In the case of use of either the braking system or the servomotor, the tendon-actuated configuration of the device makes it easy to protect against too strong a pull by incorporating a mechanical guard in the tendon which disconnects the drive element from the exoskeleton in the event of an excessive force. The exoskeleton described here can be used in combination with virtually all existing treadmills and weight relief systems. In the event of a loss of balance, a weight relief system in the form of a hanging safety belt prevents a fall.

The modular tendon-actuated exoskeleton according to the invention allows the generation of torques in the joints of a paretic leg (hip, knee and ankle) that are needed for rehabilitation training during the desired part of the gait cycle. When no torques are exerted on a leg with the exoskeleton, the latter has negligible restriction on the movement of the leg. Due to the tendon-actuated configuration of the exoskeleton, the person does not bear the weight of the actuators, therefore the mechanical impedance of the proposed exoskeleton is low. The separation of the drive part from the orthoses makes it possible to ensure the safety of the user of the device in a simple way.

The structural configuration of the modular tendon-actuated exoskeleton results in the presence of not only the forces between the segments, but also the pulling forces of the tendons, which pull the person forward towards the propulsion system. The influence of these tendons is mitigated by the use of a pulley to implement the appropriate gear ratio. In this way, the force between the segments that produces the desired torque in the gear ratio joint is greater than the force that pulls the segment forward. Undesired forward forces can be further compensated for by the use of a compensation system - an additional drive system is attached to the pelvis (or other leg segment) from the rear and pulls the body backwards.

Depending on the choice of support modules and the control of the propulsion systems associated therewith, different mechanical effects can be achieved with the modular tendon-actuated exoskeleton. Using elastic tendons in the system according to Slovenian patent application P-201900055, only swing assist can be performed. The main applications of the proposed exoskeleton are not only assistance in a swing, but also assistance in a push-off and stabilisation of the knee in a support, but also other modes of action. The support modules are configured by analogy to the monoarticular and biarticular muscles of the leg. A therapist selects an appropriate combination of support modules for each individual patient. With proper control of the propulsion system and appropriate selection of the stiffness of the connecting elements, the exoskeleton can be adapted to the needs of an individual patient.

The device can be controlled based on the detected gait events or the kinematics of the gait. Gait events can be detected from the ground reaction force data when walking on the instrumented treadmill or from kinematic data. Kinematics can be measured by inertial measurement units, by a system of markers and motion capture cameras, by additional encoders or force meters mounted on the drive elements, or by a combination of these methods.

The invention will be explained in more detail on the basis of an embodiment and the belonging drawings, in which

Figure 1 is a schematic illustration of the structural configuration of a modular tendon-actuated exoskeleton in a specific application;

Figure 2 is a structural embodiment of the propulsion system in the form of a brake system and an elastic connecting element according to the invention;

Figure 3 is a demonstration of use of the individual support modules of the modular tendon-actuated exoskeleton:

Figure 3a-1 support module VAS – start of operation;

Figure 3a-2 support module VAS – maximum force;

Figure 3a-3 support module VAS – end of operation;

Figure 3b-1 support module SOL – start of operation;

Figure 3b-2 support module SOL – maximum force;

Figure 3b-3 support module SOL – end of operation;

Figure 3c-1 support module RF – start of operation;

Figure 3c-2 support module RF – maximum force;

Figure 3c-3 support module RF – end of operation;

Figure 3d-1 support module HEEL – start of operation;

Figure 3d-2 support module HEEL – maximum force;

Figure 3d-3 support module HEEL – end of operation;

Figure 3e-1 support module HAM – start of operation;

Figure 3e-2 support module HAM – maximum force;

Figure 3e-3 support module HAM – end of operation;

Figure 3f-1 support module GAS – start of operation;

Figure 3f-2 support module GAS – maximum force;

Figure 3f-3 support module GAS – end of operation;

Figure 3g-1 support module GMAX – start of operation;

Figure 3g-2 support module GMAX – maximum force;

Figure 3g-3 support module GMAX – end of operation;

Figure 3h-1 support module ABD – start of operation;

Figure 3h-2 support module ABD – maximum force;

Figure 3h-3 support module ABD – end of operation;

Figure 3h-4 support module ABD – rear view in frontal plain.

Figure 1 is a schematic illustration of the structural configuration of a modular tendon-actuated exoskeleton in a specific application. In the example shown, the person in the picture is using two support modules at the same time: a support module SOL, which is modelled on the soleus muscle, and a support module RF, which is modelled on the rectus femoris muscle. The person has a compensation system attached to the back side.

The elements of the support module SOL and its associated propulsion system have a single line next to the numerical mark in the figure, and the elements of the support module RF and its associated propulsion system have two lines next to the numerical mark in the figure. The marks without lines represent general device elements that are not linked to a specific support module. The elements belonging to two support modules at the same time are indicated by two marks.

In the example shown, the propulsion systems are provided as a combination of connecting elements B, B', B'' in the form of a rigid tendon with a spring and braking systems A, A', A''. The connecting elements B, B', B'' may be in the form of a rigid tendon with a spring, a rigid tendon or an elastic tendon. Instead of the braking systems A, A', A'', a servomotor or an energy exchanger (as described in Slovenian patent application P-202100048) may be used to actuate the propulsion system.

The support module SOL is provided to generate plantarflexion torque in the ankle to assist in push-off. For this support module to work, a lightweight shin orthosis 3' and a dedicated shoe 4' must be arranged on the leg. A mechanical axle with three reels 5' is mounted on the back of the dedicated shoe 4' by two bearings. All three reels 5' are fixed to the mechanical axle. The outer two reels have the same radius which is greater than the radius of the middle reel. The ratio between the radii of the outer reels and the radius of the middle reel is the gear ratio of the module. A rigid string 9’ is attached to the middle reel at one end and then wound. The other end of the string 9’ is attached to a fastening arm 8’ which is fixed to the lightweight shin orthosis 3’. One end of a string 10’ is attached and wound on each of the larger reels of the element 5’. The string 10’ is wound in such a way that, when the mechanical axle with the three reels 5’ rotates, it is wound simultaneously on the two outer reels. The string 10’ is passed through a metal ring 6’ attached to the connecting element B’. The string 10’ is guided around the shin and care must be taken to ensure that it does not rub against the person during movement. This can be achieved in several ways: By using a large spacing between the two outer reels, by mounting string guides on the shoe 4’ or the shin orthosis 3’, or by using a Bowden pull.

The string 9’ is wound on the middle reel of the axle with reels 5’ in such a way that it winds when the string 10’ is unwound from the larger reels, and unwinds when the string 10’ is wound on the larger reels. When the metal ring 6’ is pulled by the braking system A’ through the connecting element B’, a force is exerted in the string 10’ which unwinds the string from the outer reels of the axle with reels 5’. This causes a torque in the axle with reels 5’, resulting in a force in the string 9’ which winds the string 9’ onto the middle reel. A force is generated between the middle reel and the fastening arm 8’ and consequently between the heel and the shin, which generates a plantarflexion torque at the ankle joint. The different radii of the reels on the axle with reels 5’ ensure that the force in the string 9’ is a gear ratio factor higher and the displacement a gear ratio factor lower than in the string 10’.

The support module RF in Figure 1 is intended to stabilise the knee shortly after stepping. For this support module to work, a lightweight pelvis orthosis 1”, a lightweight thigh orthosis 2” and a lightweight shin orthosis 3” must be arranged on the leg. A mechanical axle with three reels 5” is mounted on the lightweight shin orthosis 3” by two bearings. As in the support module SOL, the reels 5” are fixed to the axle and the outer two reels have the same radius, which is greater than the radius of the middle reel. The braking system A”, the connecting element B”, the metal ring 6” and the string 10” are interconnected and function in the same way as in the module SOL. The connecting elements B’ and B” may differ in configuration and stiffness. The propulsion systems A’ and A" may be of the same or different configuration, but always differ in the control, since the modules shown must operate in different phases of the gait cycle.

When the string 10” is unwound from the outer reels of the axle with reels 5”, the string 9” is wound on the middle reel and vice versa. The string 9” is passed through a guide 7” fixed to a thigh orthosis and is fastened to the fastening arm 8” fixed to the lightweight pelvis orthosis 1”.

The person walks on a treadmill C during the exercise.

The operation of the support modules RF and SOL also generates forces which point in the direction of the connecting elements B’, B” towards the braking systems A’, A”. Since in most modules the propulsion system is positioned in front of the walking person, the resultant of the traction forces points in the forward direction. To partially compensate for these forces pulling the body out of balance, a compensation system is attached to the person. The compensation system is provided with an additional propulsion system placed behind the walking person. In the example shown in the figure, the compensation system is provided with a braking system A and a rigid connecting tendon with a spring B, and is attached to a fastening arm 8 fixed to a lightweight pelvis orthosis 1. The braking system A can be replaced by a servomotor and the connecting element B by a rigid tendon or an elastic tendon.

Figure 2 illustrates a structural embodiment of the propulsion system in the form of a brake system and a connecting element according to the invention. A mechanical axle 13 is supported at both ends by bearings 12. Fixed to the mechanical axle 13 are a friction brake disc 14, a large diameter toothed pulley 18 and reels 16 and 22. As these elements are fixed to the axle 13, torque is exchanged between them. A string 17 is wound onto the reel 16, one end of which is attached to the reel 16 and the other end of which is attached to a spring 15. The spring 15 is attached with its other end to a frame 11. The spring 15 is a constant force spring, which means that it exerts the same force on the string 17 regardless of its extension. An alternative embodiment is to use a constant-torque spring connected to the axle 13 instead of the constant-force spring 15. Another alternative embodiment is to use a weight instead of the constant-force spring 15. A string 23 is wound onto the reel 22. The string 23 is wound onto the reel 22 with one of its ends and its other end is attached to a spring 24. The spring 24 is part of the connecting element. The other end of the spring 24 is attached to a rigid string which is connected to the selected exoskeleton module and, together with the spring, forms the connecting element, indicated by the letter B in Figure 1. The strings 17 and 23 are wound on the reels 16 and 22 in such a way that when the string 17 is unwound from the reel 16, the string 23 is wound on the reel 22 and vice versa.

The friction electromagnetic brake 14 allows the rotation of the mechanical axle 13 to be stopped almost instantaneously. Using adequate control, the friction brake 14 can be either on or off at any given moment. The elements 18, 19, 20 and 21 make up the eddy-current brake mechanism. The large diameter toothed pulley 18 rotates at the angular speed of the mechanical axle 13. The transmission of the toothed pulley 19 transfers the motion from the large diameter pulley 18 to the aluminium disc 20. A smaller diameter toothed pulley is attached to the aluminium disc 20. The gear ratio between the radii of the toothed pulleys in the transmission causes the aluminium disc 20 to rotate by a gear ratio factor faster than the axle 13. The aluminium disc 20 rotates in the air gap of the ferromagnetic core with a winding 21. By conducting an electric current through the winding, a magnetic field is created in the air gap of the ferromagnetic core 21. As the aluminium disc 20 rotates in the magnetic field, eddy currents are generated in it. The eddy currents generate a braking torque which resists the rotation of the aluminium disc 20 in proportion to its rotational speed. The braking torque is transmitted from the aluminium disc via a belt transmission back to the mechanical axle 13. The eddy-current braking mechanism has the function of a programmable mechanical damper.

In most support modules, the propulsion system associated with the module is placed in front of the person. The connecting element B is attached to the support module with one of its ends and to the braking system with another of its ends. During treadmill walking, the leg with the exoskeleton, in the gait cycle, transitions between the support phase and the swing phase. When the leg is in the support phase, it moves backwards simultaneously with the treadmill, i.e. away from the braking system. In the swing phase, the leg is moving towards a new touch point, i.e. it is moving forward at high speed towards the braking system. When the foot is moving away, in the case of friction and eddy current brakes off, the constant-force spring 15 ensures that the connecting element is in constant tension at all times. When the friction brake 14 is applied, the mechanical axle 13 stops and the spring of the connecting element 24 starts to stretch. The energy of the treadmill is stored in the spring of the connecting element 24 and at the same time the spring 24, through its associated support module, generates forces and torques on the body segments. Some support modules of the exoskeleton are configured to use the stored energy to accelerate the body segments, while others perform only the function of taking the kinetic energy from the body segments. In any case, in order to interrupt the action of the support module on the leg segments, it is necessary to disengage the friction brake and allow the axle 13 to rotate again. When disengaged, due to the residual energy in the spring 24, a transient phenomenon and oscillation of the springs 24 and 15 occur. The oscillations are damped and the energy is dissipated from the system by the eddy-current brake 18, 19, 20 and 21.

Figure 3 illustrates use of the individual support modules of the modular tendon-actuated exoskeleton. The figures only show a person, a treadmill and individual support modules. The compensation system is not shown for illustrative purposes. Depending on the patient's needs, several support modules can be used simultaneously. Each support module in Figures 3a to 3g is illustrated by three figures. The figures show the operation of the support modules in the sagittal plane. Four figures are shown for the support module ABD. In addition to three figures showing the operation in the sagittal plane, a figure of the frontal plane view has been added for illustrative purposes.

The first figure in each support module 3x-1 shows the moment in the gait cycle when we start using that support module. If the braking system is applied, this is when the friction brake is applied. The second figure of each support module 3x-2 shows the moment when the forces and torques exerted by the module on the person are maximal. The third figure of each support module 3x-3 shows the moment in the gait cycle when the operation of this support module is finished. In the case of the application of the braking system, this is the moment when all remaining energy that has been stored in the connecting element has either been used to accelerate the leg segment motion or has been dissipated at the eddy-current brake. From the 3x-3 moment to the 3x-1 moment in the next gait cycle, the effect of the support module on gait is negligible.

The figures 3a-1 to 3a-3 show the support module VAS which operates by analogy with the vasti muscles. A fastening arm is attached to the front side of the thigh orthosis. The shin orthosis has at the front side mounted an axle with three reels, similar to the support modules in Figure 1.

The figures 3b-1 to 3b-3 show the support module SOL which operates by analogy with the soleus muscle. A fastening arm is attached to the rear side of the shin orthosis. The dedicated shoe has an axle with three reels mounted at the rear. The support module SOL is shown in more detail in Figure 1, where its elements are indicated by a single line.

The figures 3c-1 to 3c-3 show the support module RF which operates by analogy with the rectus femoris muscle. A fastening arm is attached to the front side of the pelvis orthosis. A guide for a string is attached on the thigh orthosis. The shin orthosis has at the front side mounted an axle with three reels. The support module RF is shown in more detail in Figure 1, where its elements are indicated by two lines.

The support module HEEL in Figures 3d-1 to 3d-3 does not use reels, but the connecting element is attached to a customised fastening arm which is attached to the rear side of the dedicated shoe. The fastening arm is formed in a way to allow two strings to be attached to the two ends of the fastening arm so that the strings can be passed around the foot without rubbing against it. This support module only allows the application of force to the heel and is intended to assist in push-off.

The figures 3e-1 to 3-e3 show the support module HAM which operates by analogy with the biceps femoris muscle. A fastening arm is attached to the rear side of the pelvis orthosis. A guide for a string is attached on the thigh orthosis. The shin orthosis has at the rear side mounted an axle with three reels, similar to the support modules in Figure 1. As the use of this support module is foreseen in the swing phase, the treadmill energy storage is not possible. The propulsion system in this module is placed behind the person.

The figures 3f-1 to 3f-3 show the support module GAS which operates by analogy with the gastrocnemius muscle. A fastening arm is attached to the rear side of the thigh orthosis. A guide for a string is attached on the shin orthosis. The dedicated shoe has at the rear side mounted an axle with three reels, similar to the support modules in Figure 1.

Figure 3g shows the functioning of the support module GMAX which operates by analogy with the gluteus maximus muscle. A fastening arm is attached to the rear side of the pelvis orthosis. The thigh orthosis has at the rear side mounted an axle with three reels, similar to the support modules in Figure 1.

The support module ABD in Figures 3h-1 to 3h-4 is the only one that is not intended to operate in the sagittal plane, but allows the hip abduction torque to be applied in the frontal plane. A fastening arm is attached at the side of the pelvis orthosis. An axle with two reels is mounted on the thigh orthosis. The reels are fixed to the axle. When the string is wound onto the large diameter reel, it unwinds from the smaller diameter reel and vice versa. For illustrative purposes, in addition to Figures 3h-1, 3h-2 and 3h-3, Figure 3h-4 has been added to show the support module in the frontal plane from the rear side.

CLAIMS

1. A modular tendon-actuated exoskeleton for gait training,

   characterized by

   consisting of one or more support modules and a compensation system, where the support modules and the compensation system are connected via connecting elements (B, B', B'') to braking systems (A, A', A'').

2. The modular tendon-actuated exoskeleton for gait training according to claim 1,

   characterized in

   that the brake system (A, A', A'') consists of a mechanical axle (13) that is provided at its both ends with bearings (12) and on which a friction brake disc (14), a large diameter toothed pulley (18) and reels (16, 22) are attached, wherein a string (17) is wound onto the reel (16), one end of which is attached to the reel (16) and the other end of which is attached to a spring (15), and the spring (15) is attached with its other end to a frame (11); a string (23) is wound onto the reel (22), one end of which is attached to the reel (22) and the other end of which is attached to one end of a spring (24) that is part of the connecting mechanism (B, B', B''), wherein the other end of the spring (24) is attached to a rigid string which is connected to the selected exoskeleton support module, and the strings (17, 23) are wound on the reels (16, 22) in such a way that when the string (17) is unwound from the reel (16), the string (23) is wound on the reel (22) and vice versa.

3. The modular tendon-actuated exoskeleton for gait training according to claim 2,

   characterized in

that a constant-torque spring connected to the axle (13) is used instead of the constant-force spring (15) or that a weight is used instead of the constant-force spring (15).

4. The modular tendon-actuated exoskeleton for gait training according to the preceding claims 1-3,

   characterized in

   that a support system (VAS) is used, which consists of a lightweight thigh orthosis, a lightweight shin orthosis, to which a reel is arranged as indicated on Figure 3a-1 and described on pages 11 and 12.

5. The modular tendon-actuated exoskeleton for gait training according to the preceding claims 1-3,

   characterized in

   that a support system (SOL) is used, which consists of a lightweight shin orthosis, to which a reel is arranged as indicated on Figure 3b-1 and described on pages 11 and 12.

6. The modular tendon-actuated exoskeleton for gait training according to the preceding claims 1-3,

   characterized in

   that a support system (RF) is used, which consists of a pelvis orthosis, a lightweight thigh orthosis, a lightweight shin orthosis, to which a reel is arranged as indicated on Figure 3c-1 and described on pages 11 and 12.

7. The modular tendon-actuated exoskeleton for gait training according to the preceding claims 1-3,

   characterized in

that a support system (HEEL) is used, which consists of a connecting element attached to an adapted fastening arm that is fastened to a rear side of a dedicated shoe as indicated on Figure 3d-1 and described on pages 11 and 12.

8. The modular tendon-actuated exoskeleton for gait training according to the preceding claims 1-3,

   characterized in

   that a support system (HAM) is used, which consists of a pelvis orthosis, a lightweight thigh orthosis, a lightweight shin orthosis, to which a reel is arranged as indicated on Figure 3e-1 and described on pages 11 and 12.

9. The modular tendon-actuated exoskeleton for gait training according to the preceding claims 1-3,

   characterized in

   that a support system (GMAX) is used, which consists of a lightweight thigh orthosis, a lightweight shin orthosis, to which a reel is arranged as indicated on Figure 3f-1 and described on pages 11 and 12.

10. The modular tendon-actuated exoskeleton for gait training according to the preceding claims 1-3,

    characterized in

    that a support system (GAS) is used, which consists of a lightweight thigh orthosis, to which a reel is arranged as indicated on Figure 3g-1 and described on pages 11 and 12.

11. The modular tendon-actuated exoskeleton for gait training according to the preceding claims 1-3,

characterized in

that a support system (ABD) is used, which consists of a pelvis orthosis, to which a fastening arm is attached at a side, and an axle with two reels is mounted on the thigh orthosis as indicated on Figure 3h-1 and described on pages 11 and 12.

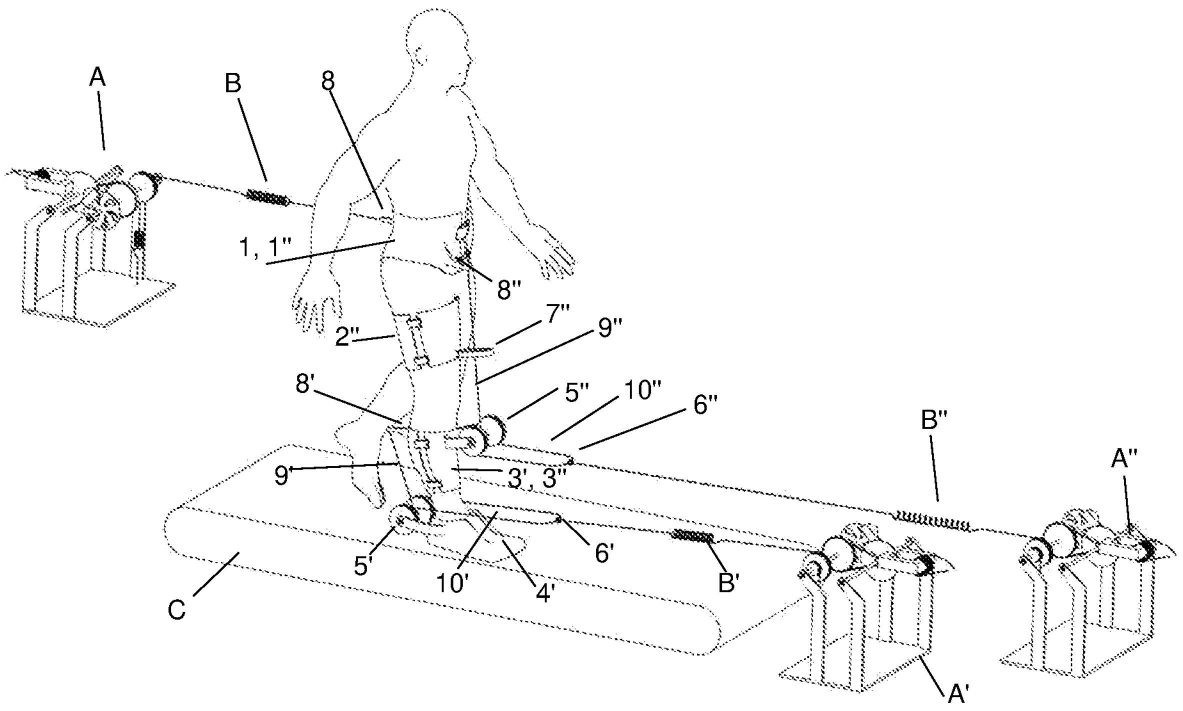
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Fig. 1

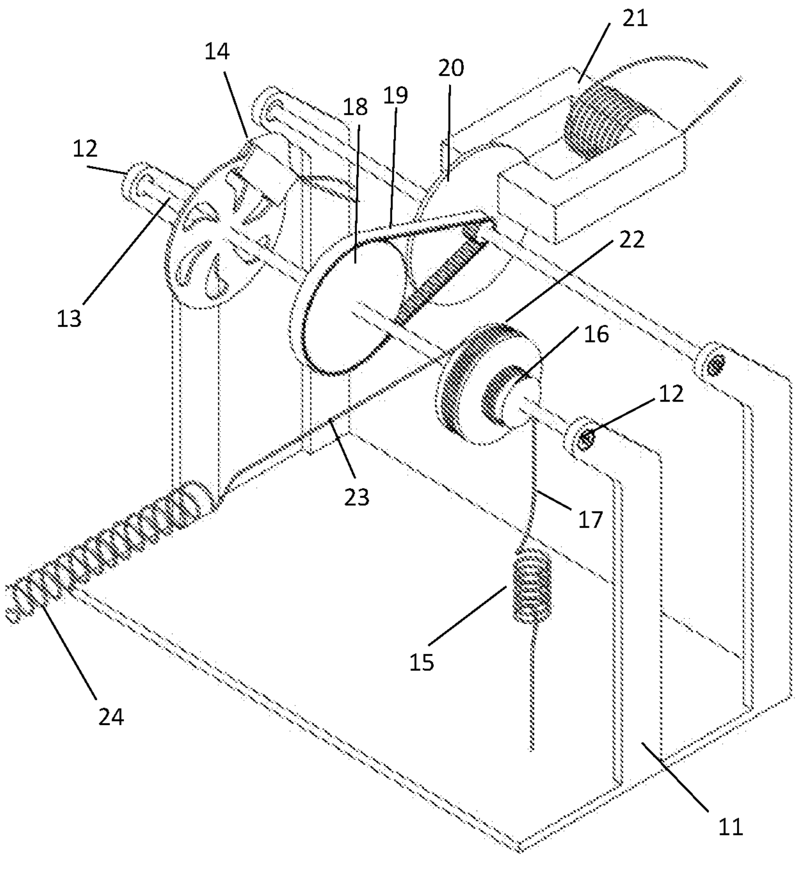
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Fig. 2

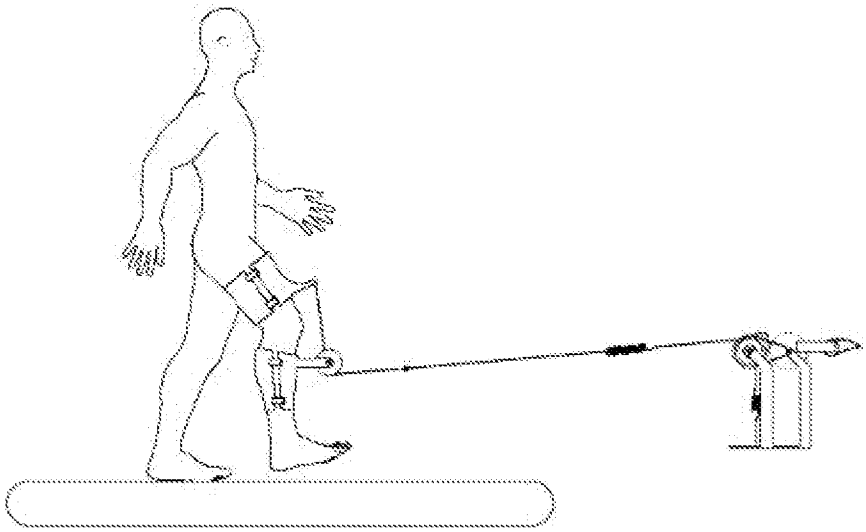


Fig. 3a-1

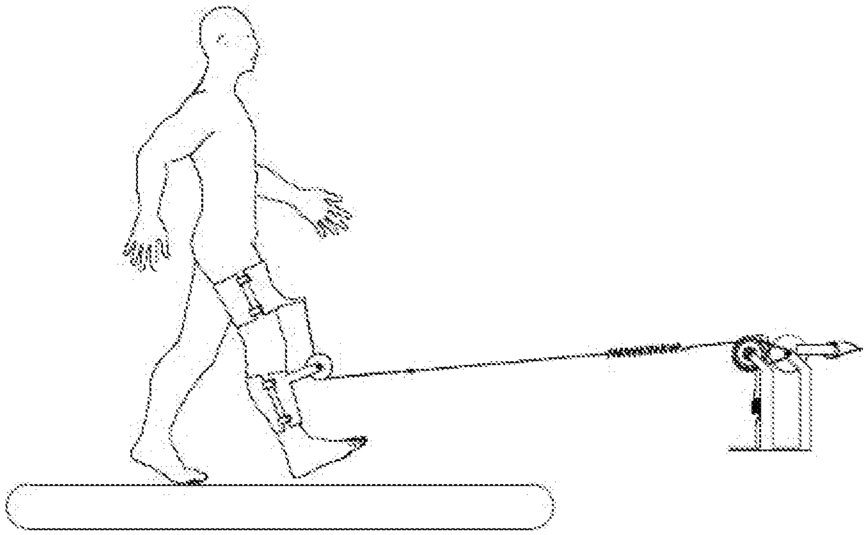


Fig. 3a-2

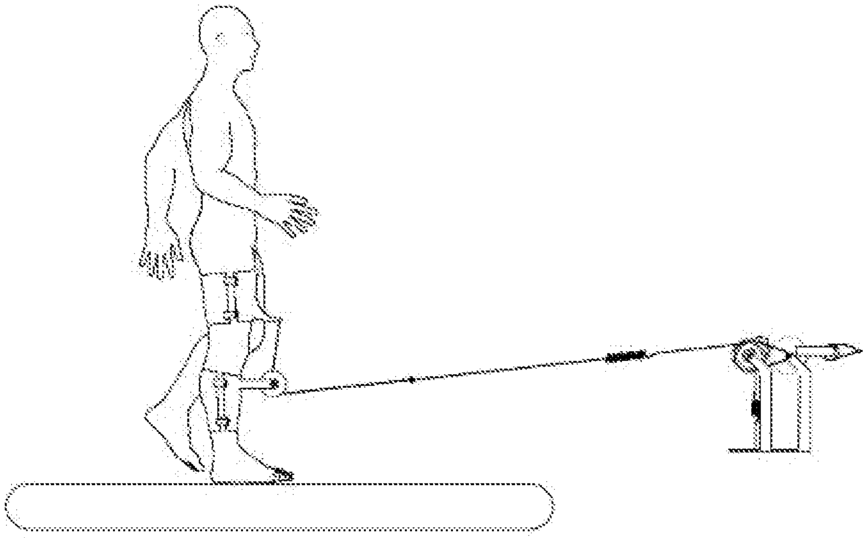


Fig. 3a-3

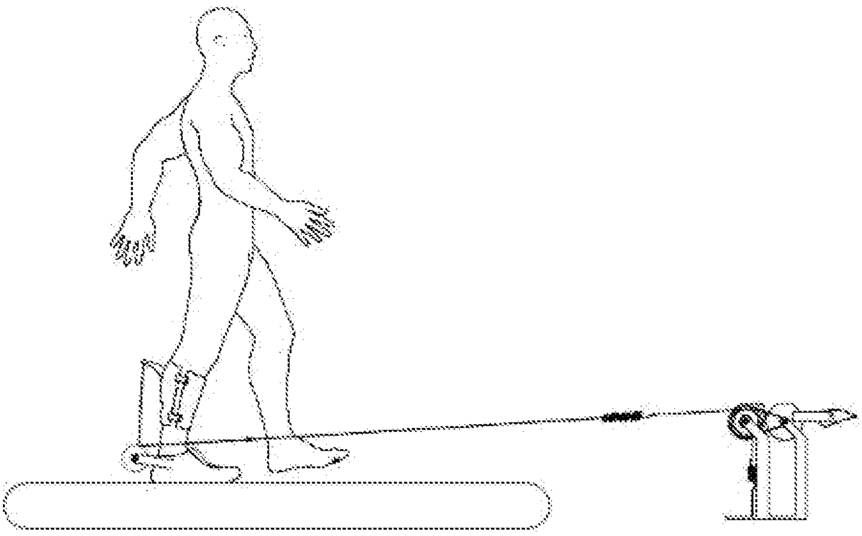


Fig. 3b-1

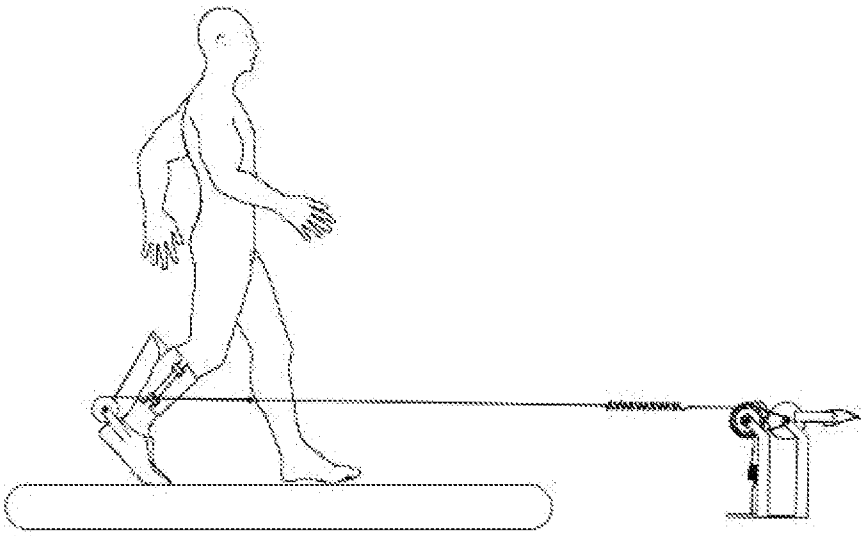


Fig. 3b-2

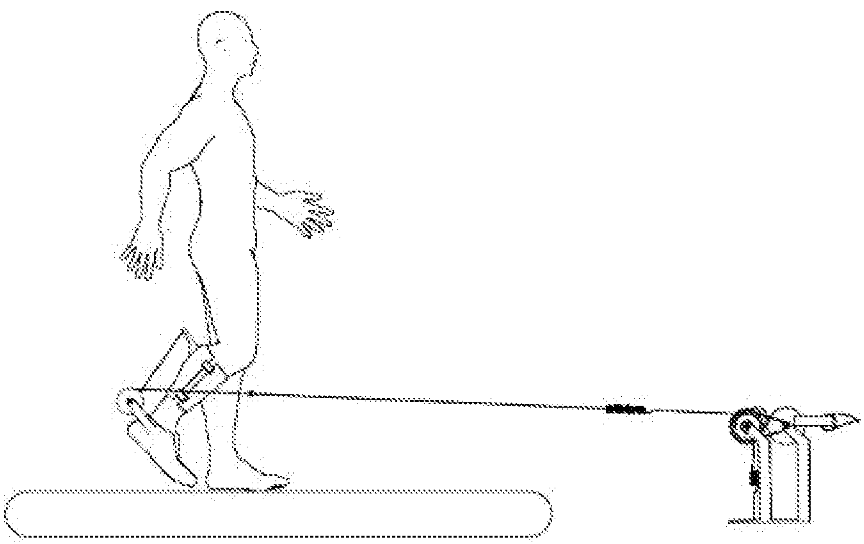


Fig. 3b-3

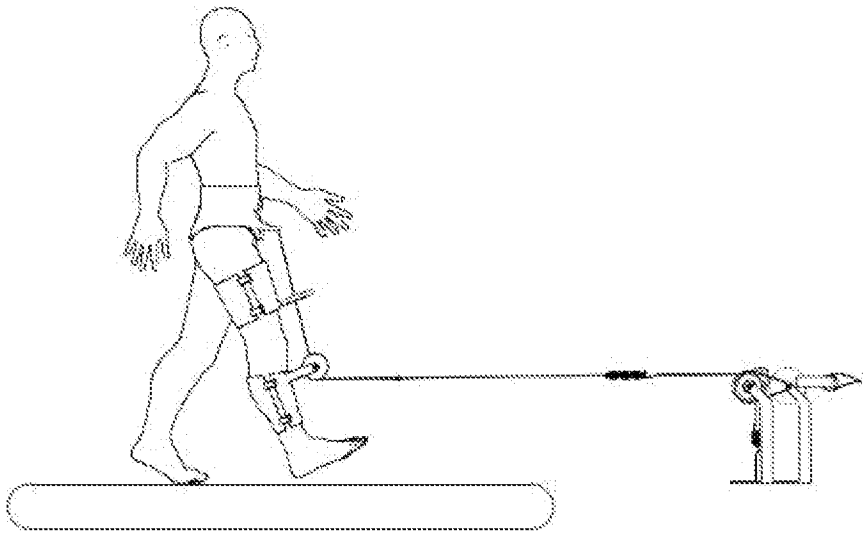


Fig. 3c-1

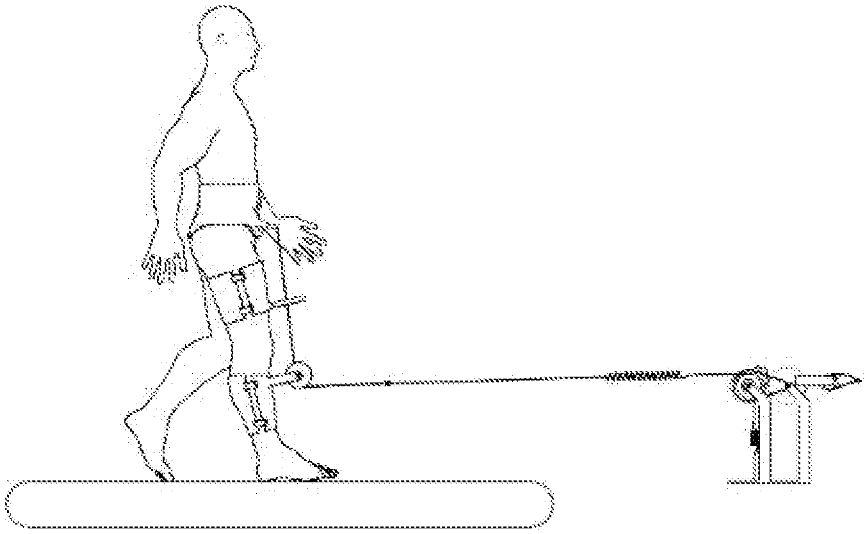


Fig. 3c-2

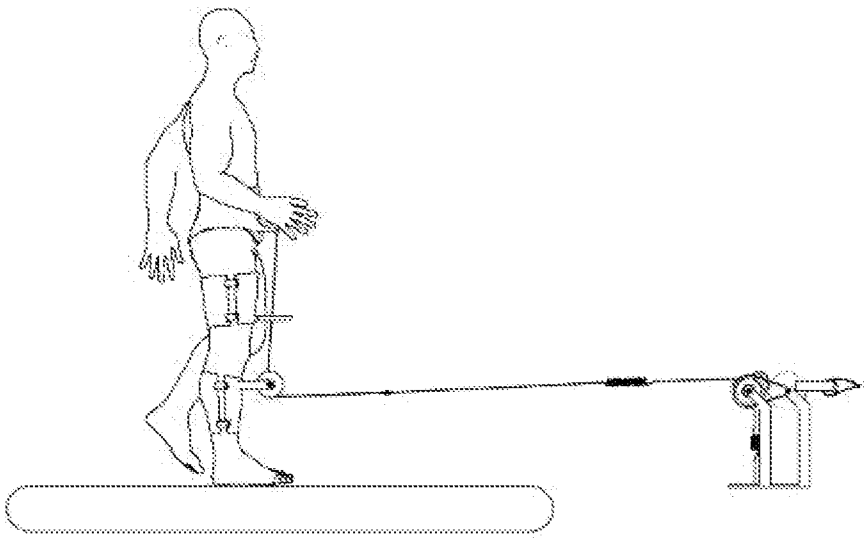


Fig. 3c-3

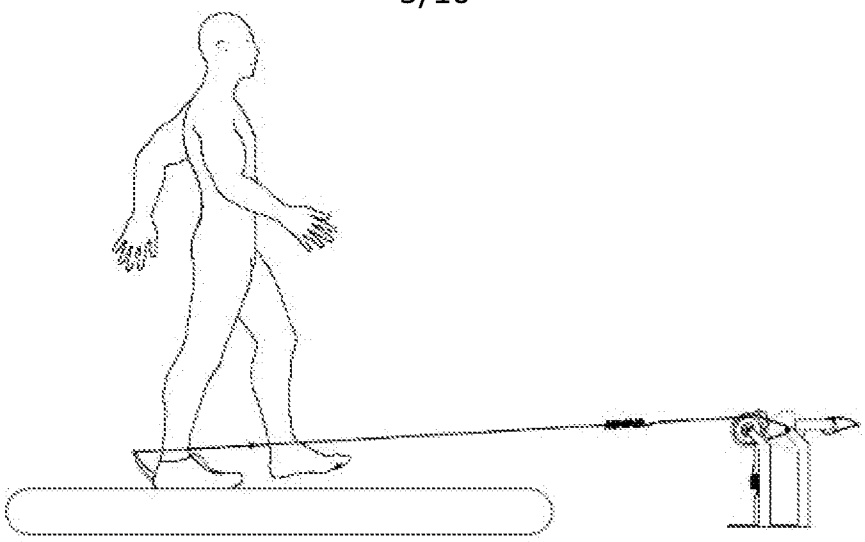


Fig. 3d-1

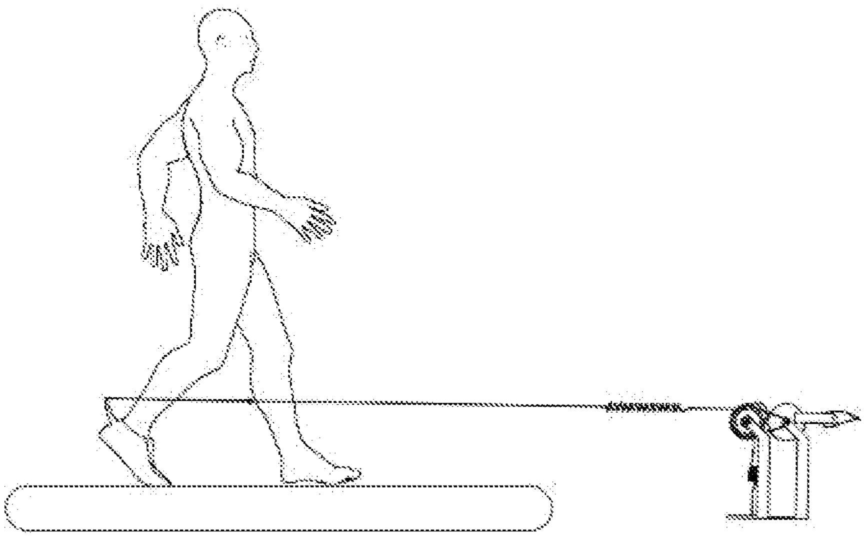


Fig. 3d-2

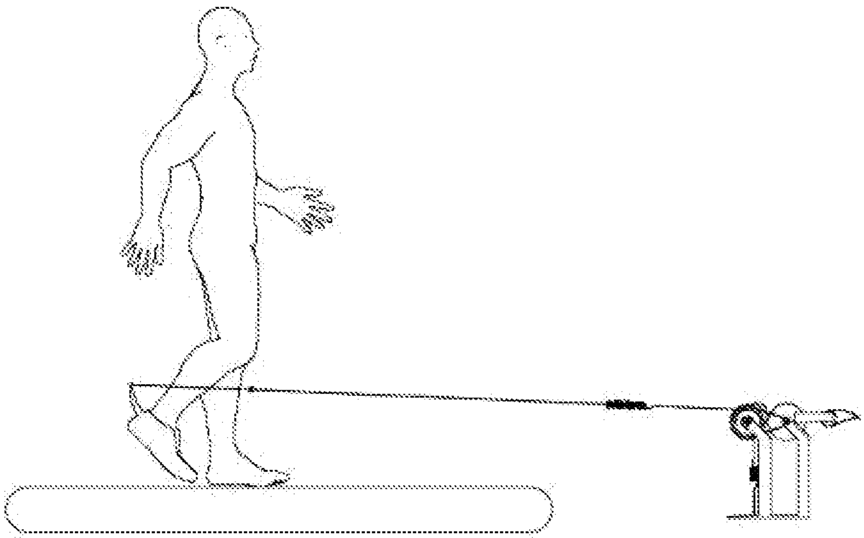


Fig. 3d-3

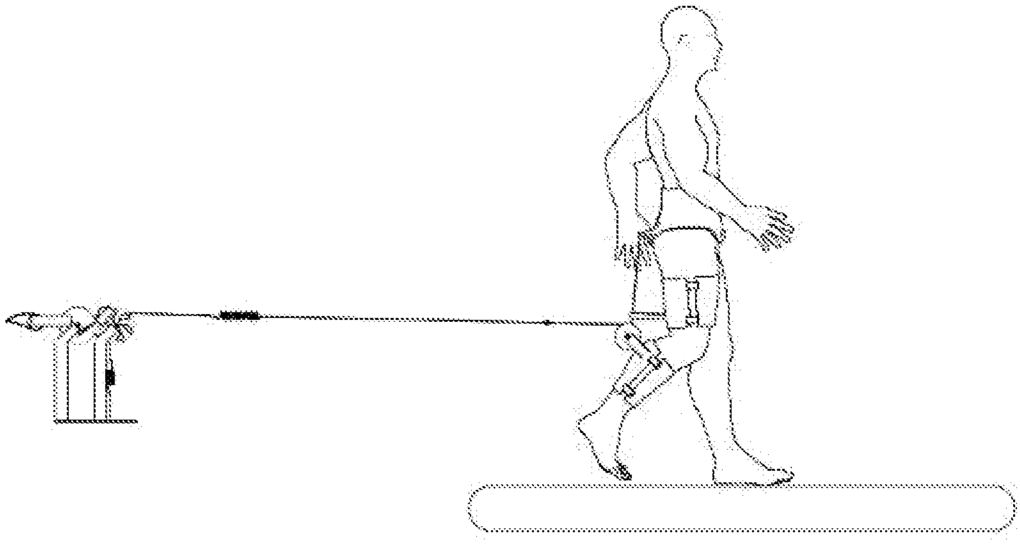
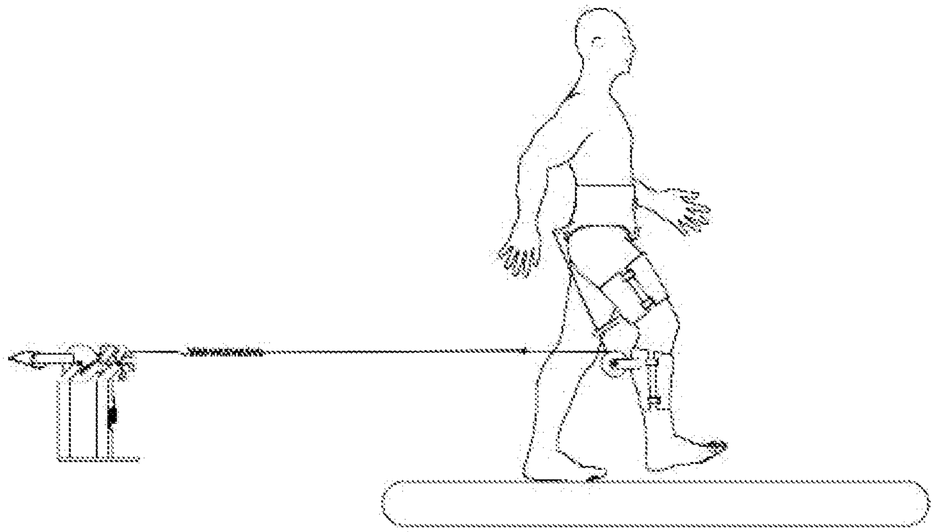


Fig. 3e-1



Slika 3e-2

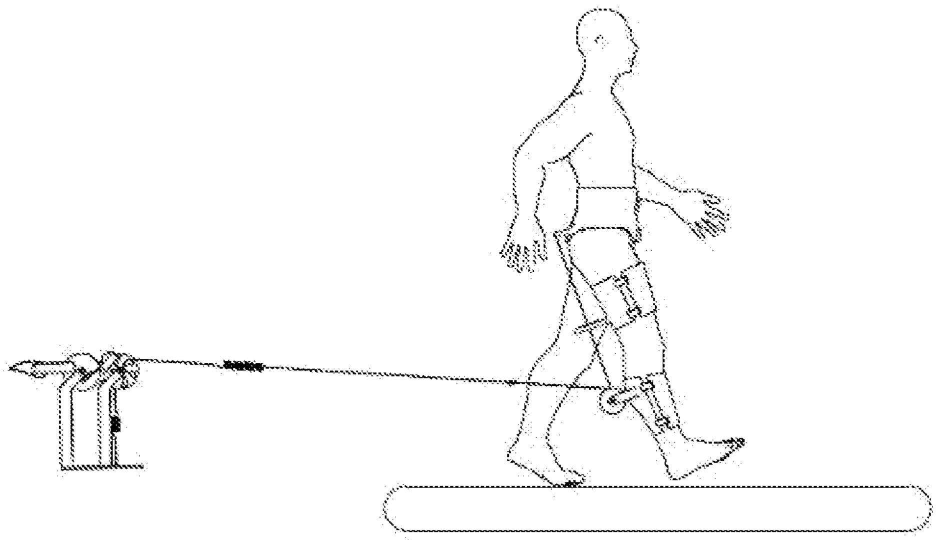


Fig. 3e-3

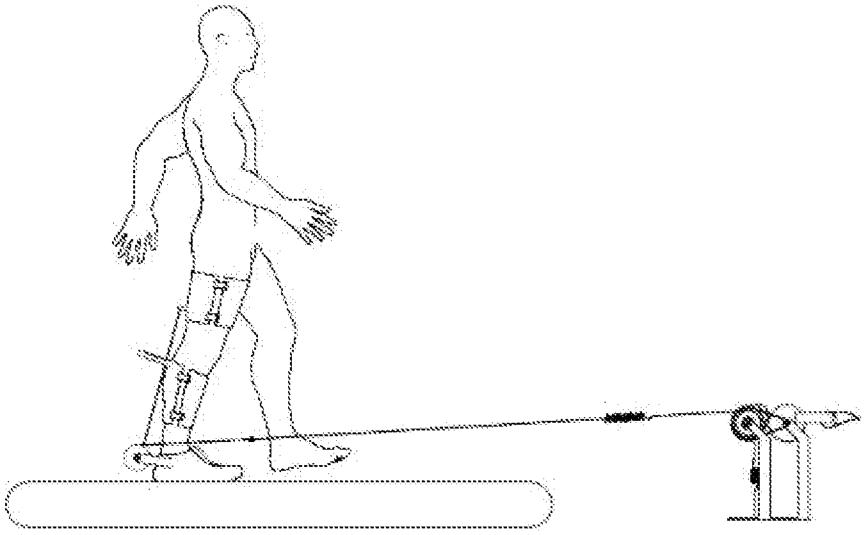


Fig. 3f-1

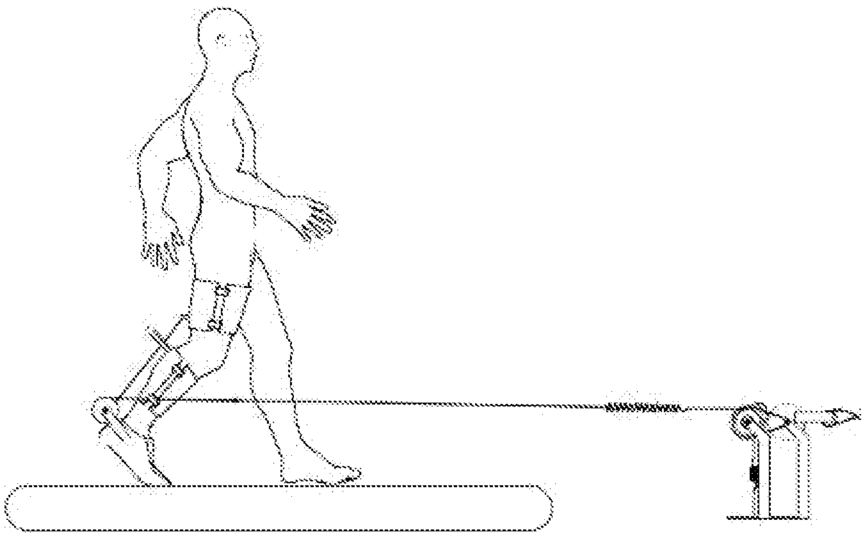


Fig. 3f-2

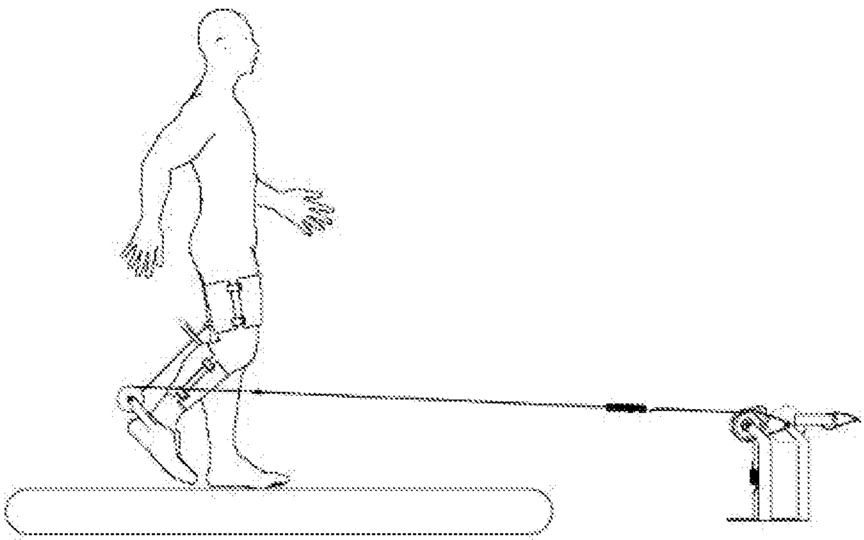


Fig. 3f-3

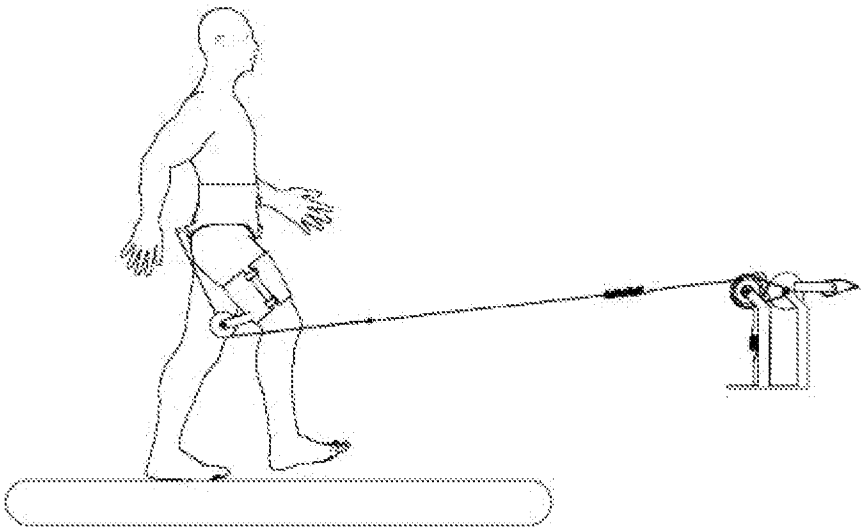


Fig. 3g-1

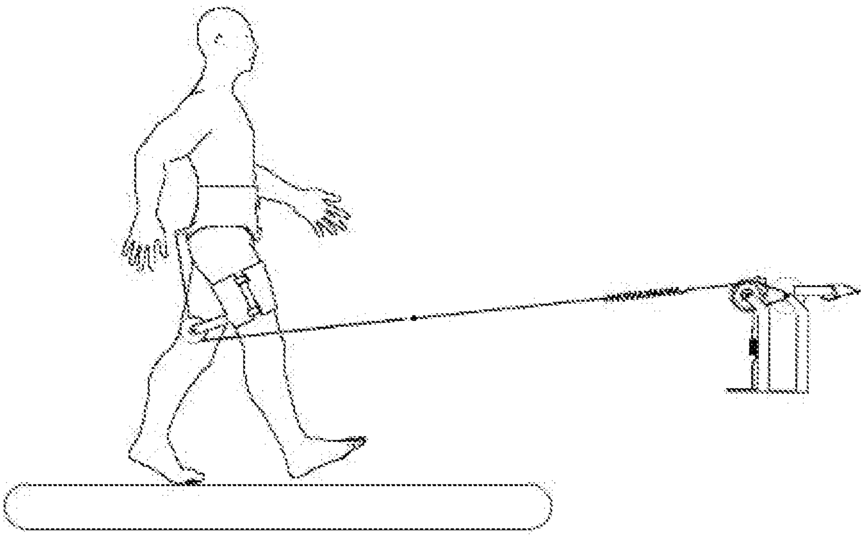


Fig. 3g-2

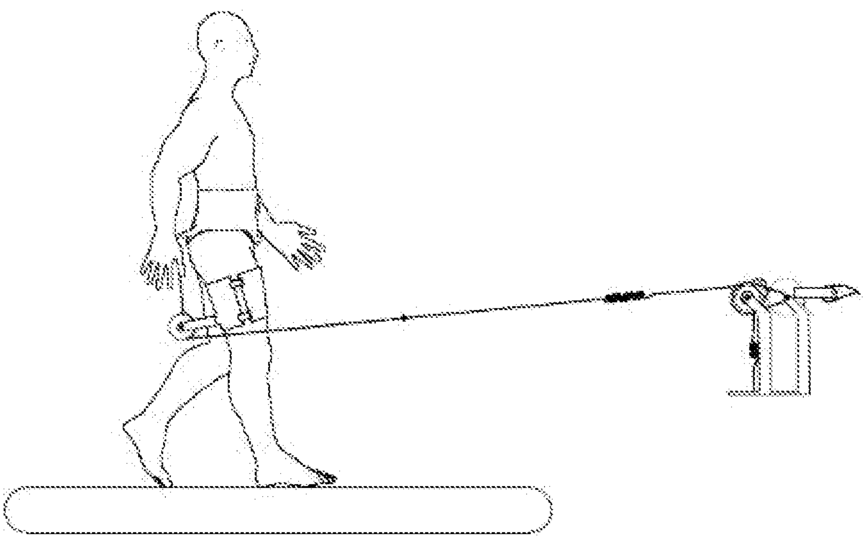


Fig. 3g-3

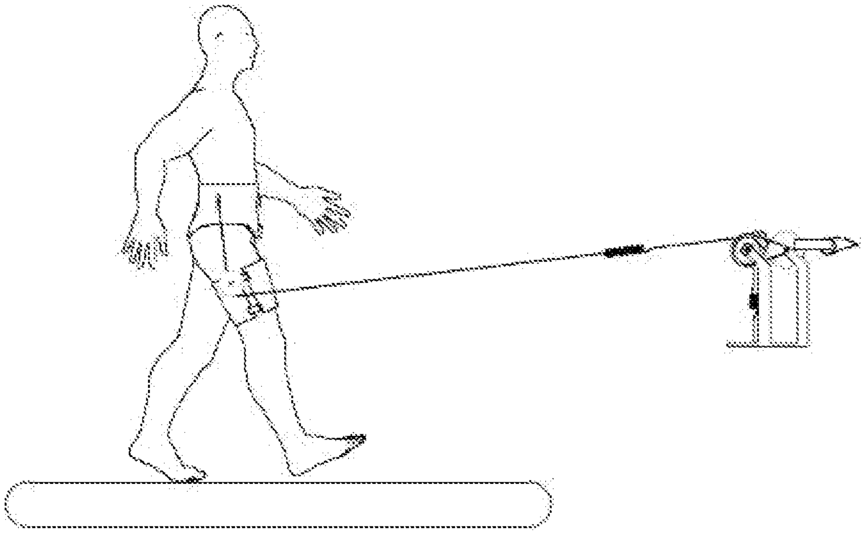


Fig. 3h-1

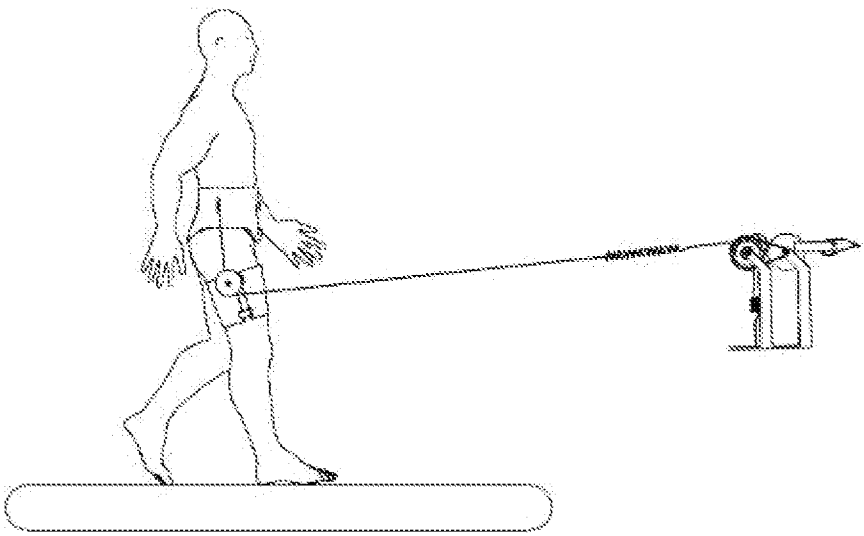


Fig. 3h-2

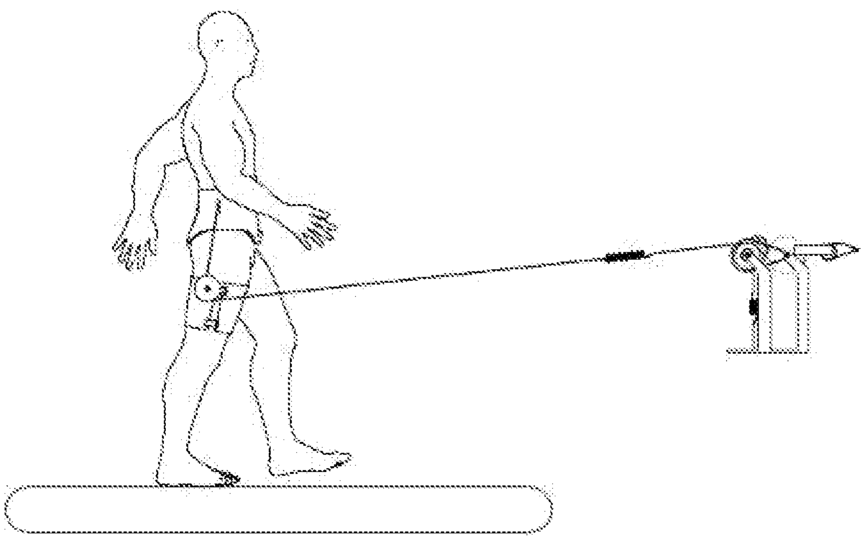


Fig. 3h-3

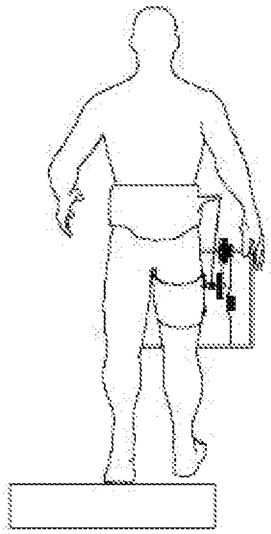


Fig. 3h-4

INTERNATIONAL SEARCH REPORT

International application No
PCT/SI2022/050019

A. CLASSIFICATION OF SUBJECT MATTER
INV. A61H1/02 A61H3/00 A63B21/00 A63B21/015 A63B22/00
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
A61H A63B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	US 2006/229167 A1 (KRAM RODGER [US] ET AL) 12 October 2006 (2006-10-12) paragraph [0011] - paragraph [0021]; figures	1 2,3
Y	US 2012/245003 A1 (MIRCHEV GEORGI ASENOV [BG] ET AL) 27 September 2012 (2012-09-27) figures	2,3
X	US 2011/275043 A1 (LIU WEN [US]) 10 November 2011 (2011-11-10) figures	1
X	US 6 123 649 A (LEE R CLAYTON [US] ET AL) 26 September 2000 (2000-09-26) figures	1

-/--

[x] Further documents are listed in the continuation of Box C.

[x] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance;; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance;; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
19 October 2022	28/10/2022

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Squeri, Michele

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2017/065478 A1 (TAKASHIMA MASAYUKI [JP]) 9 March 2017 (2017-03-09) figures -----	1-3
A	US 2018/326243 A1 (BADI ABDELHAK [CA] ET AL) 15 November 2018 (2018-11-15) figures -----	1-3

1

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SI2022/050019

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☒ Claims Nos.: 4-11
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
see FURTHER INFORMATION sheet PCT/ISA/210

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims;; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

Continuation of Box II.2

Claims Nos.: 4-11

Claims 4-11 are not clear since they rely, in respect of the technical features of the invention, on references to the description or drawings (Rule 6.2(a) PCT).
These claims were not searched.

The applicant's attention is drawn to the fact that claims relating to inventions in respect of which no international search report has been established need not be the subject of an international preliminary examination (Rule 66.1(e) PCT). The applicant is advised that the EPO policy when acting as an International Preliminary Examining Authority is normally not to carry out a preliminary examination on matter which has not been searched. This is the case irrespective of whether or not the claims are amended following receipt of the search report or during any Chapter II procedure. If the application proceeds into the regional phase before the EPO, the applicant is reminded that a search may be carried out during examination before the EPO (see EPO Guidelines C-IV, 7.2), should the problems which led to the Article 17(2) PCT declaration be overcome.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/SI2022/050019

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2006229167 A1	12-10-2006	NONE	
US 2012245003 A1	27-09-2012	NONE	
US 2011275043 A1	10-11-2011	NONE	
US 6123649 A	26-09-2000	NONE	
US 2017065478 A1	09-03-2017	CN 106511036 A	22-03-2017
		EP 3141232 A1	15-03-2017
		JP 6323419 B2	16-05-2018
		JP 2017051427 A	16-03-2017
		KR 20170030440 A	17-03-2017
		US 2017065478 A1	09-03-2017
US 2018326243 A1	15-11-2018	CA 3006115 A1	01-06-2017
		US 2018326243 A1	15-11-2018
		WO 2017088055 A1	01-06-2017