ELECTROMECHANICAL PROSTHETIC DEVICES FOR THE CONTROL OF MOVEMENTS IN HANDICAPPED INDIVIDUALS
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ABSTRACT OF THE DISCLOSURE

An electromechanical gait rehabilitation system wherein a pressure actuated sensing device is provided for generating a signal representative of an element of the basic mechanism of normal human gait to control a motor means which is connected to a body support member for pivoting the body support member about an articulated connection with a band that is adapted to encircle the pelvic region of an individual having at least one disabled or missing leg.

This invention relates to the management of the handicapped, and is more particularly concerned with apparatus for artificially inducing movements by electronic techniques.

This invention is based upon a consideration of two types of voluntary action:

(A) An automatic servo-mechanism with a closed loop, comprising a sensor, a motor and a sensor, again. This type of voluntary control dominates the movement of the lower extremities, particularly during gait. Thus, the right leg does not begin its swing forward, until the left foot has established a firm contact with the ground; resulting in a sensory feedback towards the centers of coordinated locomotion. The swing of this right leg elicits the contraction of muscles which decelerates this leg to the point of inducing the right heel contact, which in turn elicits the swing of the left leg, etc. This phenomenon operates in a type of "chain reaction."

(B) A second type of voluntary action is expressed by the continuous or intermittent conscious action initiating, interrupting or reversing the control of the first type or else entirely responsible for the movement, as for instance the cutting out of a pattern with a pair of scissors. This type of movement changes with mental attitude and predominates for the movements of the upper extremities. I have found that the balance between the conscious and the automatic control of movements determines their character; and with respect to the hand, the consciously controlled movement is more prevalent than for those in the lower extremities. Additionally, voluntary movements—and particularly voluntary movements of the hand—are dominated by spatial cues. In other words, these movements have for their initial goal the task of bringing a part of the body, e.g., fingertips, to a desired point in space, regardless of the pathway leading the hand to this point, muscle coordination or movement speed necessary to achieve this goal. When one tries to grasp or touch an object, one does not think which muscles have to be activated for this purpose, or which movements of shoulder, head or elbow are necessary to achieve contact between the fingers and object; one simply has in mind the expectation of bringing the fingers to the place where the object is located and receiving appropriate perception of the object, e.g., sensory feedback. This ability of the cerebral control mechanisms to bring a part of the body to a point in space also applies to any tool or object connected to any body part.

A further voluntary mechanism of particular importance is that ordinarily, except in the case of very slow and continually controlled movement, the innervation of the muscles is timed at the beginning and at the end of a voluntary act (i.e., "push-pull"). In order to terminate this act, the innervation is directed towards the antagonist of the prime mover so that the movement is stopped. During the rest of the time, cerebral control relies on the forces of inertia and gravity to maintain the movement in the proper direction.

A further mechanism of voluntary movement is the consideration that whenever a habitual movement cannot be performed, a substitute movement with a distant part of the body is automatically brought into action in order to attain this goal. Thus, the brain transfers or "delegates" the necessary innervation to the muscles which are not usually involved in the movement.

I have found it desirable to employ these principles of voluntary mechanism and voluntary action in the construction of artificial tensor devices for ensuring movement of a desired part of the human body. It is, therefore, one object of the invention to provide an electromechanical rehabilitation device in which there is included means for sensing a preselected periodic or aperiodic movement of a portion of the body, and means for ensuring a concomitant desired coordinated movement of another body portion.

A further object of the invention is the provision of an electromechanical gait rehabilitation device in which means are provided for sensing the position of a human body portion functioning as an element of the basic mechanism of normal human gait, and including means for ensuring articulation of a leg brace in a predetermined sequence imitative of the natural principles of voluntary movement of a leg member.

A still further object of the invention is to provide a gait rehabilitation device for specific application to hemiplegic subjects.

A still further object of the invention is to provide a gait rehabilitation device for a specific application to a paraplegic subject.

These and further objects of the invention will become more readily apparent upon a reading of the description following hereinafter, and upon an examination of the drawings, in which:

FIG. 1 is a side perspective view indicating the invention as applied to a gait rehabilitation device for a hemiplegic subject;

FIGS. 2 and 3 are side views in outline configuration illustrating successive positions of an artificial lower extremity incorporating locking mechanisms for the knee joints; and

FIGS. 4 and 5 are somewhat schematic representations of successive positions of gait rehabilitative devices including locking mechanisms for the knee joint.

As indicated in the drawings the invention is directed to an electromechanical device for rehabilitating a movement which cannot be performed either because of a weakness or because of paralysis or amputation. The invention ensures the imitation of the natural principles of volun-
tary movements as far as possible. I have found that the classical view somewhat exaggerated the role of the gastrocnemius as the prime propeller of the body during locomotion, while the role of flexors and extensors of the hip has been generally underestimated. I have further found that the gluteus maximus evinces a remarkable co-ordination with the hip flexors and the gastrocnemius. This coordination was found to be ingenious in that when the flexors swing the leg forward, the gluteus maximus on the opposite side prevents the torso from bending forward and thus maintains the erect posture. I have further observed that the gluteus maximus activity starts by making the corresponding leg "grasp" the ground at the time of the heel contact, just as if it were the oar of a boat. Thus, it contributes to the effort of the other leg about to leave the ground to push the body forward (e.g., a "push-pull" mechanism).

FIG. 1 illustrates the application of the invention to a long leg brace 8 which is articulatedly connected to a pelvic circumventing band or pelvic corset 6. The subject 1 is a hemiplegic and therefore a single gear-reduced motor 10 is employed. A switch 12 is placed in the shoe of the normal leg 2, and by appropriate circuitry (not shown) it is connected to turn the motor on in one direction when the normal leg is on the floor, and in the reverse direction when the normal leg swings forward. At that time, the paralyzed leg 3 is on the floor and the reverse action of the motor contributes to the extension of the knee. In this way the stride of the involved leg is increased as well as facilitated when climbing stairs. Balance may be assured by using a pair of crutches 14, or a single crutch. The device illustrated in FIG. 1 may also be modified to be employed for a paraplegic patient with a stable back who is able to lift his foot from the floor. In such an arrangement two electric motors would be employed, one on each side of the pelvic member 6, and attached in the manner illustrated in FIG. 1 to a hip or long leg brace. The electric motors would be capable of driving the leg braces in opposite directions and automatically controlled by a pair of switches 12 placed in each shoe. The opening of the shoe switch would activate the motor on the ipsilateral side in the direction of swinging the foot forward, and simultaneously the motor on the contralateral side will drive this joint in the reverse direction, which is expressed by maintaining the trunk extended.

Of major importance in obtaining confidence of a subject is the prevention of buckling of the knee mechanism during stance and affording a more-or-less controlled sliding. The sliding mechanism is most resilient; as indicated in FIGS. 2 and 3, it may be achieved by employing an electro-magnet 16 mounted on an artificial leg member 18, which is articulated at 20 to an upper artificial leg member 22. The electro-magnet 16 is actuated by the switch 12 which is connected thereto and to a power source 26 by an appropriate electrical circuit 24. The electro-magnet 16 is so arranged as to be actuated to lock the knee joint 20 at the time of the stance-induced closure of the shoe switch 12, and to unlock the knee joint 20 when the shoe switch 12 is open (see FIG. 3). With particular application to the artificial leg member, a power source and control box 34 is mounted to a pelvic circumventing member 36. An artificial leg member is appropriately articulated to the pelvic member 36 at joint 40, which joint has combined therewith a drive motor 50 which is appropriately connected to an electrical circuit including the power supply 34, a shoe switch 52 and an electrical solenoid 54. The solenoid 54 is mounted upon the training leg 56 and serves to lock a ratchet and pawl mechanism when the switch 52 is energized (see FIG. 4). When the switch 52 is opened, then the solenoid 54 is de-energized to permit racheting of the mechanism 58 as the leg member 38 is driven forwardly.

Although specific embodiments of the invention have been described, it is to be understood that various changes and modifications and rearrangements may be made while still remaining within the spirit and scope of the invention.

What I claim is:

1. An electromechanical gait rehabilitation system for use by an individual having at least one disabled or missing leg comprising: a band adapted to encircle the pelvic region of the individual; a body support member having an upper portion and a lower portion adapted to engage the floor; means providing an articulated connection between the upper portion of said support member and said band; motor means connected to said support member for pivoting said support member about said articulated connection; and circuit means for controlling said motor means, said circuit means including a source of power for said motor means and a sensing device for generating a signal representative of an element of the basic mechanism of normal human gait in response to pressure applied thereto by said individual for energizing said motor means to pivot said body support member in one direction.

2. The system of claim 1 in which said body support member is a leg brace adapted to be mounted on the disabled leg of a hemiplegic subject, said motor means being a reversible electric motor and said sensing device being a switch connected in said circuit and adapted to be positioned in the shoe of the normal leg of the subject, whereby said motor means pivots said leg brace in one direction when said normal leg is on the floor and in the reverse direction when said normal leg swings off the floor.

3. The system of claim 1 in which the body support member is a prosthetic leg the upper portion of which is a thigh simulating member and the lower portion of which is a calf simulating member, said upper and lower portions being joined by an articulated connection that provides a simulated knee joint, and means for locking said knee joint in a stance position.

4. The system of claim 3 in which said sensing device is mounted on the lower portion of said prosthetic leg, said locking means being an electromagnetic device connected in said circuit means so that knee joint locking means is actuated by the signal generated by said sensing device.

5. An electromechanical gait rehabilitation system for use by a paraplegic individual comprising: a band adapted to encircle the pelvic region of the individual; a pair of body supporting leg braces each adapted to be mounted on one disabled leg, each brace having an upper portion and a lower portion adapted to engage the floor; means providing an articulated connection between the upper portion of each brace and said band; a pair of reversible electric motors; each connected to one brace for pivoting the braces about their respective articulated connections; and circuit means for controlling said motors, said circuit means including a source of power for said motor means and a pair of sensing devices for generating signals representative of an element of the basic mechanism of normal human gait in response to pressure applied thereto by said individual, each sensing device being adapted to be positioned in one shoe of the subject, the signal generated by one sensing device being transmitted to the other sensing device in the ipsilateral side in the direction to swing the associated leg brace forward, while simultaneously the motor on the contralateral side operates to swing the associated leg brace in the reverse direction.

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