device is an active muscle assistance device. The active assistance device is configured with an exoskeletal frame that attaches to the outside of the body, e.g., lower limb, and transmits an assist or resist force generated by the actuator. The active assistance device provides primarily muscle support although it is capable of additionally providing joint support (hence the name "active muscle assistance device"). As compared to passive support devices, this device does not add extra strain to other muscle groups. The active muscle assistance device is designed to operate in a number of modes. In one operation mode it is designed to provide additional power to muscles for enhancing mobility. In another operation mode, it is designed to provide resistance to the muscle to aid in rehabilitation and strength training. The active muscle assistance device is attached to a limb or other part of the body through straps or other functional bracing. It thus provides muscle and/or joint support while allowing the individual easy maneuverability as compared to the wheelchair-assisted maneuverability. An individual can be fitted with more than one active muscle support device to assist different muscles and to compensate for weakness in a group of muscles (such as leg and ankle) or bilateral weaknesses (such as weak quadriceps muscles affecting the extension of both knees).

[0013] The active muscle support device is driven by an actuator, such as motor, linear actuator, or artificial muscle that is powered by a portable power source such as a battery, all of which fit in a relatively small casing attached to the muscle support device. Many types of actuators can be used in this device. However, to reduce weight, the preferred actuator is one made primarily of polymers and using high voltage activation to provide power based on electrostatic attraction. In one embodiment such actuator is an electrostatic actuator operative, when energized, to exert force between the stationary and moving portions. In this case, the energizing of the electrostatic actuator is controllable for directing the force it exerts so that, when assisting, the force reduces the muscle stress, and, when resisting, the force opposes the joint movement.

[0014] A microcontroller-based control system drives control information to the actuator, receives user input from a control panel function, and receives sensor information including joint position and external applied forces. Based on the sensor input and desired operation mode, the control system applies forces to resist the muscle, assist the muscle, or to allow the muscle to move the joint freely. The control system controls the manner in which the actuator is energized for directing the force so that, when assisting, the force reduces the muscle stress and, when resisting, the force opposes joint movement.

[0015] In one embodiment of the present invention, a computer system for controlling joint movement is provided. Such computer system includes: a processing unit (microcontroller, microprocessor, etc.) and a memory, both of which operate with the detection means (sensors), and the actuator (preferably electrostatic). The detection means is operative to detect joint movement and muscle stress. The memory has program code for causing the processing unit to receive an indication as to which mode of operation is selected and in response thereto obtain from the detector means, based on the selected mode, an indicia of muscle stress or joint movement, or both. The processor activates the actuator or maintains it idle based on the selected mode of operation and indicia. The available modes of operation include: idle, assist, rehabilitate, resist and monitor mode. For instance, in the assist and rehabilitate modes, the actuator is activated to assist in reducing the muscle stress; and in the resist mode the actuator is activated to resist the joint movement.

[0016] In another embodiment, a method is proposed for controlling joint movement and reducing muscle stress. The method includes fastening a powered muscle assistance device with an actuator at points above and below a joint; setting a desired mode of operation of the powered muscle assistance device; detecting, at the powered muscle assistance device, an indicia of joint movement or muscle stress with flexion or extension of the joint; and activating the actuator to exert force. Again, in the assist and rehabilitate modes, the actuator is activated to assist in reducing the muscle stress; and in the resist mode the actuator is activated to resist the joint movement.

[0017] As can be appreciated, this approach provides a practical solution for muscle augmentation, for rehabilitation through resistance training, for allowing free movement and for monitoring movement. These and other features, aspects and advantages of the present invention will become better understood from the description herein and accompanying drawings.

BREIF DESCRIPTION OF THE DRAWINGS

[0018] The accompanying drawings which, are incorporated in and constitute a part of this specification, illustrate several embodiments of the invention and together with the description, serve to explain the principles of the invention.

[0019] **FIG. 1** shows an embodiment of the invention in the form of an active knee brace.

[0020] **FIGS. 2***a-f* illustrate the respective structure and operation of electrostatic actuators.

[0021] **FIG. 3** is a diagram showing the mechanical linkage between the actuator and the body attachment brace.

[0022] **FIG. 4** is a block diagram showing the electronics used to drive and control the active muscle assistance device.

[0023] **FIG. 5** is flowchart showing the modes of operation of a muscle assistance device.

[0024] **FIG. 6** is a flowchart of the modes of operation of a knee joint muscle assistance device.

DETAILED DESCRIPTION OF THE INVENTION

GENERAL OVERVIEW OF A KNEE BRACE

[0025] **FIG. 1** shows an active muscle support brace according to one embodiment of the invention. The device is an active knee brace used to offload some of the stress from the quadriceps when extending the leg. For different parts of the body, other devices are constructed with a suitable shape, but the principles presented here apply by analogy to such devices. The device is particularly useful in helping someone with muscle weakness in the every day tasks of standing, sitting, walking, climbing stairs and descending stairs. The device can also be used in other