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Single Channel Hybrid FES Gait Assist System

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Loss of mobility due to lower limb paralysis is common consequence of thoracic level spinal cord injury (SCI). In the US there are approximately 253,000 persons with SCI. The wheelchair is the most common form of mobility for individuals with paraplegia but there remains a need for assistive technology that can enable paraplegics to walk and reach in the periphery of wheelchair. A new concept is presented that combines functional electrical stimulation (FES) with an energy storing orthosis (ESO) that contains a fluid power system to store and transfer energy during the gait cycle. Elastic energy storage elements on the orthosis hip and knee joints hold the leg in a flexed equilibrium position. Stimulation of the quadriceps extends the knee, placing excess energy in both the equilibrium spring and an energy transfer element. The stored energy is transferred to the hip where it is discharged and used to extend the hip against its equilibrium spring which also aids in forward progression. A new step is initiated by releasing the hip and knee joints from the straight leg position to the flexed position. The concept is realized using gas springs and pneumatic cylinders. Gas springs act as flexed energy storage elements. Lower air cylinder and the tubing acts as an accumulator and the upper cylinder acts as hip joint actuator. The system uses 2 way proportional solenoid actuated pneumatic valves for control during extension. The conceptual design of the ESO was completed and implemented in a dynamic simulation model (MSC ADAMS) and in a benchtop prototype for engineering measurements. Of the 14 joules of energy available from quadriceps, 8.9 joules of energy is utilized for doing work against springs and inertial forces; 5.4 joules is stored in pneumatic system; of which 1.4 joules is required for hip extensions and the remaining will be used for forward progression. No studies were conducted with human subjects. A hydraulic fluid power system was investigated for better control and braking possibilities but was not adopted because of difficulities in accumulator design and high fluid friction losses. A Matlab code was used to calculate the torques required at joints to support standing. Commerical braces are being used for improved user comfort. A wrap spring brake is being designed to maintain standing posture without FES or any active energy input. Technical feasibility of the ESO prototype will be evaluated using two subjects with paraplegia.

Improved Cardiopulmonary Resucitation Device

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Cardio-pulmonary resuscitation (CPR) plays an important role in the outcome of sudden cardiac arrest, where survival rates continue to be very low, about 5%. CPR has evolved significantly from the days when it was standard practice to flap the arms of victimes, or roll their bodies back and forth over a wooden barrel. Today, many people know the standard technique of giving chest compressions. Others may know about enhancement devices (e.g., ResQPOD) that use a basic mechanics concept of creating negative thoracic pressure during the decompression phase of CPR. This is done by adding inflow resistance to the patient's airway, such that a vacuum is created at each chest decompression. The vacuum pulls blood into the thorax, in effect "priming the pump" with more blood, which is then ejected in the next compression phase. We present an enhancement to the above proven concept of airway restriction during CPR by further adding total airway occlusion to the inflow and outflow of air at appropriate times, by use of a CPR enhancement device (CED). With a face mask and electronic airway valve, maximal vacuum and positive pressures are created in the thorax to enhance blood circulation during cardiac arrest. A CPR cycle is proposed with five phases including two for free air exchange, without the need to interrupt compressions, and adhering to AHA guidelines of 100 compressions per minute. To test the CED, a human cardiopulmonary model is described that allows blood pressure changes to be measured with the various forms of CPR, new and conventional. Preliminary data from testing both CED and standard CPR on the thorax model were found in terms of mean, systolic and diastolic pressure. T-tests evaluated statistical significance. During normal CPR, average systolic pressure was found to be 35.3 ± 0.6 mmHg. When the CED was applied, the average systolic pressure was found to be 62.9 ± 4.5 mmHg ($p=0.0002$). Average diastolic pressure for normal CPR was found to be 30.4 ± 0.4 mmHg while that of the CED was observed to be 28.6 ± 1.2 mmHg ($p=0.095$, NS). The MAP calculated from standard CPR resulted in an average of 32.0 ± 0.4 mmHg, while that using the CED was 40 ± 2.1 mmHg, ($p=0.002$). Based on this preliminary testing and data analysis, the CED shows a significant improvement in systolic and mean arterial pressure in comparison to standard CPR. This supports the CED five phase method that provides positive pressure and vacuum in the cardiopulmonary system during resuscitation. Future work will compare the CED to other CPR enhancement devices.

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