Biomechanical Energy Analysis and Functional Evaluation of a Lower Limb Energy Harvesting and Transmission Exoskeleton

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Research

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Abstract

Background: Human beings are constantly adjusting their strategies to adapt to the new environment along with the rapid evolution and development. Scientists have made great effort to collect the energy consumed by walking and provide it as energy input to join the energy circulation system. It can be utilized to rehabilitation training, walking assistance and energy compensation of patients with mild hemiplegia. Methods: Based on the clinical medical viewpoint of healthy side teaching the affected side, through harvesting the energy of the healthy side of the lower limb, release it when the affected side works, to realize the movement assistance independently. Therefore, this paper describes an energy harvesting and transmission exoskeleton (EHTE) to achieve the biomechanical energy harvest, management, and transmission. The human experiment and function evaluation was carried out to explore the influence mechanism on the main muscles of human lower limbs. The data acquired by the sEMG experiment, and sEMG signals were recorded. Results: The result shows that EHTE can reduce the strength and activity of some muscles and achieve ipsilateral and contralateral lower limb assistance. The sEMG signal of muscle changes considerably during walking with EHTE, which indicates that muscle contraction has enhanced. Conclusions: It suggested that the body adjusts physiological changes automatically to adapt to energy transmission during walking. EHTE provides a potential solution to enhance exercise ability, prolong the joint life, delay the development of disease and improve the quality of life.

Full Text

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Figures

Figure 1

Flexion and extension in the sagittal plane. (a) Tibial-on-femoral perspective. (b) Femoral-on-tibial perspective.

Figure 2

Recording and interpreting electrical activities emitted from activated skeletal muscles (EMG). (a) The generating process of EMG. (b) Advantage of EMG in muscle evaluation.

Figure 3

The main muscles of human lower limbs. (a) Knee joint and muscles. (b) Ankle joint and muscles.

Figure 4

Rigid five-bar model. (a) Human walking. (b) Human musculoskeletal system. (c) The reference coordinate system. The reference coordinate system (coordinate system 0) is defined at the heel of standing leg. Local coordinate system is set up to each rod. Origins of coordinate system 1, 2, 3 separately fixed at the ankle joint, knee joint, hip joint of the standing leg; origins of coordinate 4, 5, 6 separately fixed at the hip joint, knee joint, ankle joint of the swing leg. (d) Dynamic model of single leg support phase. (e) Dynamic model of double legs supporting phase. (f) Three degree of freedom linkage system.

(b)

(c)

Figure 5

Gait experiment and analysis. (a) Data acquisition of human lower limb movement with optical motion capture system. (b) Calibration of human musculoskeletal model. (c) Walking experiment.

Figure 6

The study of human lower extremity during the gait cycle. (a) OpenSim inverse kinematic analysis diagram. (b) The comparison of experimental and simulation results of lower limb joint torque.

Figure 7

Energy conversion during walking. (a) Transfer between potential and kinetic energy during gait [36]. (b) The energy release of human lower limbs [32]. (c) The energy flow and the expenditure of a human body during walking. (d) The energy flow and the expenditure of a human body during walking while wearing the energy harvester.

Figure 8

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Figure 9

The structure of the human lower limb energy harvesting and transmission exoskeleton. (a) The three dimensional structure of exoskeleton transmission box. (b) Explosive view of the energy harvester [37].

Figure 10

sEMG experiment with subject. (a) The selected muscle for sEMG experiment. (b) View of the prototype lower limb exoskeleton. (c) Human experimentation setup with EMG and insole plantar pressure tester. (d) The walking experiment on the treadmill.

Figure 11

sEMG experiment walking on the treadmill. (a) The first group of EMG experiment (EMG block was pasted on the left leg). (b) The second group of EMG experiment (EMG block was pasted on the right leg).

Figure 12

EMG experiment of subject. (a) The influence of exoskeleton on the input lower limb (EMG attached to right leg). (b) The influence of exoskeleton on the output lower limb. (EMG attached to left leg).