Inter-limb energy transfer on mechanics and energetics of walking

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1 Motivation

Mechanical work for step-to-step transition has been considered as a major determinant of the metabolic cost for human gait [1, 2]. Therefore the overall cost of walking should decrease if the mechanical work during step-to-step transition is reduced. The purpose of this study is to test this hypothesis using a passive inter-limb device that decreases the mechanical work by facilitating mechanical energy transfer between the legs during step-to-step transition.

2 State of the Art

Current lower limb gait assistive devices reduce joint work performed by the muscles through either external work input to the body [3] or through energy transfer between different phases of the gait cycle [4]. Currently no device performs inter-limb mechanical energy transfer during step-to-step transition even though this period is critical to the metabolic cost of walking.

3 Approach

We developed a passive inter-limb device consisting of an elastic cable and a set of pulleys that connects the feet such that energy can be transferred between the legs during the step-to-step transition period. The initial length of the cable and elastic elements were chosen based on the shortest subject so that no slack developed in the elastic cable and the elastics did not enter the pulleys during pre-swing. A hook clip is connected at the ends of the elastic elements to provide easy donning and doffing with the pulley cable and foot attachments. The foot attachments used are commercially available 5-point foot harness (Nautilus Inc). The effective spring constant is approximately 81N/m and the weight of the device is approximately 1kg. A visual representation of the device is presented in Figure 1.

As previously mentioned, the function of the device is to transfer energy from the leading leg to the trailing leg during step-to-step transition. Maximum deflection of the elastic elements occurs during the redirection of the COM (heel-strike) and minimum deflection occurs during the swing phase.

With assistance from the elastic cable, the device simultaneously reduces heel-strike impact of the leading leg and push-off force of the trailing leg. Consequently, the positive mechanical work performed by the trailing leg and negative mechanical work performed by the leading leg should be reduced. The device should have minimal effects throughout the remainder of the gait cycle other than the step-to-step transition.

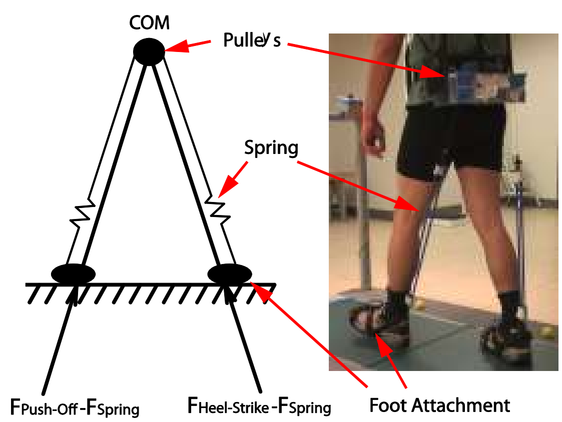

Figure 1: Inter-limb energy transfer device configuration

Preliminary testing was conducted with 5 male subjects (age: 23.4 ± 2.7 yrs, mass: 71.0 ± 10.7 kg, height: 176.3 ± 6.0 cm, mean ± 1 S.D). Subjects were given a 5-10min acclimation period while wearing the device on the treadmill after which a resting metabolic rate was measured during 10mins of quiet sitting.

The subjects' metabolic rate (COSMED) and ground reaction force were collected during

10mins of walking on a force treadmill (AMTI) under two conditions: 1) with the device in active mode and 2) with the device in passive mode. In active mode the subject's legs are coupled through the elastic cable allowing energy exchange during step-to-step transition while in passive mode the subject simply wears the device as a backpack. The metabolic and mechanical cost of transport (COT) was determined following the procedures from [5]. The subject's step length was calculated as the product of step period and treadmill speed.

4 Current Results

For all of the subjects, their mechanical COT for the leading and trailing leg decreased when walking with the device in active mode while their metabolic COT increased. Subject step length also decreased when walking with the device in active mode. A summary of the results is presented in Figure 2.

5 Discussion

Contrary to what we expected, the metabolic COT did not decrease when the mechanical COT was reduced. A possible explanation for the divergence is the change in joint work. However, the effects on joint level work and specific contribution of the device while walking have not been conducted at this time. The change in step length would also change the subject's metabolic expenditure and decrease the subject's mechanical work performed during step-to-step transition. The exact effects of the device are not clear and the results seem contradict the claim that the step-to-step transition is a major determinant of metabolic cost during human gait.

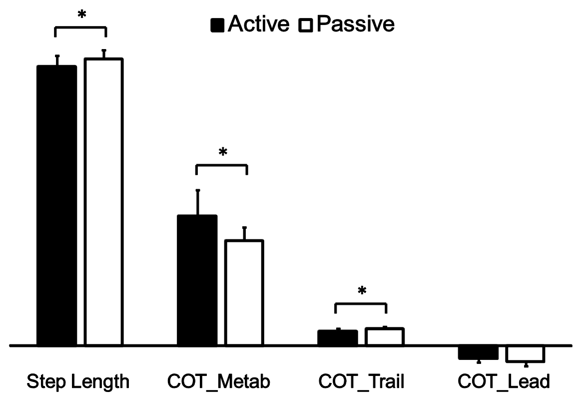

Figure 2: Change in step-length, metabolic COT and mechanical COT is presented, with the asterisk indicating a significant difference. Units of step length are in meters while the COT parameters are non-dimensional.

Acknowledgement

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