



Ankle Push-off and Mechanical Energy Flow in Human Gait

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INTRODUCTION

Studies on the role of ankle push-off in human walking have not reached a unified conclusion. The term "push-off" in literature mostly means the power source for propulsion and might have been misleading.

The objective of this research was to study the ankle push-off function in view of the effect of the ankle push-off power on the mechanical energy flow pattern of lower extremity. An energy flow model of human gait was developed in order to analyze the utilization of the ankle push-off power comprehensively and intuitively. The model presented a new perspective of gait biomechanics by bridging the joint and segmental energetics and gave an explicit way to show the energy flow pattern of lower extremity and the utilization of joint power. We hypothesized that the ankle push-off power would be a power source for preparing the following swing of lower-limb segments, but not for pushing the superincumbent body forward.

METHOD

Subjects: 10 able-bodied young subjects.

Apparatus: A gait laboratory equipped with Optotrak motion system and two AMTI force plates.

Procedures: Subjects were asked to walk with shoes along a 10-meter walkway at self-selected speed. Kinematic and kinetic data were collected.

Data Analysis: Joint powers (ground, ankle, knee and hip) and segmental energy change rate (foot, shank and thigh) of the right leg during a gait cycle were analyzed. The energy flow pattern at the instant of the peak ankle power generation was depicted to discuss the joint power utilization.

RESULTS

By taking the mean value, an energy flow pattern of the right leg at the peak instant of ankle push-off is shown in Figure 1. The Joints are marked with circled plus (generation) or minus (absorption) signs. Squared upwards (or downwards) arrows from bar are for the segments, where upwards direction means increase in energy change. The thick arrows were used to depict the energy flow either going from a joint to a segment or the other way around. All numbers are the amount of energy flow in Watt/Kg.

From the right end of Figure 1, we see that the ground produced 0.03 Watt/Kg flowing into the foot. To make the foot energy increase by 0.09 Watt/Kg, it implies (not shown) the foot required an inflow of 0.06 Watt/Kg, which was provided by the ankle. The ankle generated push-off power of 2.3 Watt/Kg flowing into

the shank by 2.24 Watt/Kg in addition to the flow of 0.06 Watt/Kg into the foot. The shank utilized 0.93 Watt/Kg and passed 1.31 Watt/Kg to the knee, which absorbed 1.03 Watt/Kg and released 0.28 Watt/Kg to the thigh. Because this amount of energy flow was not sufficient for the thigh to match its energy increase at 0.54 Watt/Kg, the hip supplied the thigh with 0.26 Watt/Kg, which was the surplus of the hip joint power over the pelvis distal inflow, i.e., $1.27 - 1.01$ (Watt/Kg). Figure 2 shows the positive proximal flow of the thigh during pre-swing.

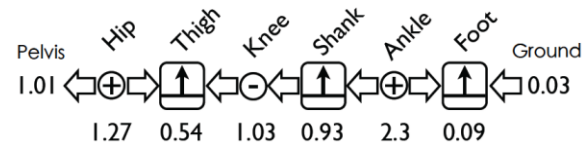


Figure 1. An energy flow pattern at the peak of ankle push-off power generation.

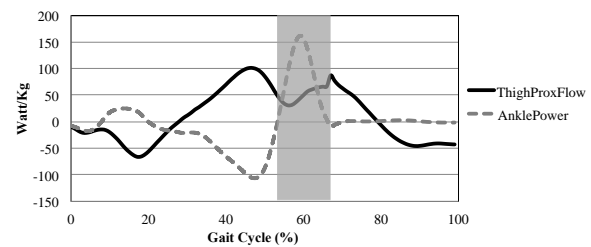


Figure 2. Thigh proximal inflow during pre-swing (gray area).

DISCUSSION

This study reveals that during walking the pre-swing movement of the thigh requires the hip joint power in addition to the ankle joint power. It also indicates the ankle joint power during push-off is consumed by the shank, the knee and the thigh, and there is no spillover of ankle power into the hip to influence the movement of the pelvis and above segments.

CONCLUSION

The ankle push-off supplies energy to the shank, the knee and the thigh for the preparation of the following swing in walking at self-selected speed.

CLINICAL APPLICATIONS

The energy flow model of human gait can be used to analyze the utilization of the ankle push-off power for the design of prosthetic and orthotic devices.

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