UNDERLYING MECHANISMS OF OBSERVED SEGMENT KINEMATICS IN HUMAN GAIT

[1] Susanne Lipfert, [1]Michael Günther, [1]Sten Grimmer and [1]Andre Seyfarth

[1]Lauflabor Locomotion Lab, University of Jena, Germany

email: s.lipf@uni-jena.de, web: www.lauflabor.de

INTRODUCTION

Simple mechanical models consisting of a point mass equal to the body mass together with massless legs have been utilized to describe and predict the basic mechanics behind human locomotion [1, 2]. Spring-like leg operation as described by Geyer's [1] spring-mass model is found in human running as well as in human walking. However, it is not known what enables humans to walk and run at the same speed. The present study aims at identifying to what extent the segmented leg operates differently when humans walk compared to when they run.

METHODS

To reveal the role of leg segmentation during human locomotion over a range of speeds that could be covered by both gaits, we measured kinematics of walking and running at five different speeds (0.5 m s^{-1} to 2.6 m s^{-1}). A total of 11011 individual steps of 21 subjects (10 male, 11 female) were analyzed. We recorded data using an instrumented treadmill (ADAL3D-WR, Tecmachine) and eight wall-mounted high-speed infra-red cameras (Qualisys). For that, 15 reflective markers were placed over anatomical landmarks of the subjects' lower limbs. Recordings were conducted simultaneously. Depending on their individually preferred transition speed (PTS), subjects were required to walk and run at five different speeds (25, 50, 75, 100, 125% PTS). Gait cycles were defined by two subsequent touch-down events. Inner joint angles were calculated between adjacent segments. Joint angular accelerations were calculated by twice differentiating the angular time traces using a central difference approximation.

RESULTS AND DISCUSSION

As expected, we found gait-specific joint kinematics during the contact phases of walking and running (Fig. 1). Within the gait cycle, however, a surprising similarity was present in the upper leg kinematics between both gaits, which even increased with speed. By contrast, ankle joint function was decoupled from the knee joint in walking but synchronized with the knee joint in running, thus defined the gait-specific contact scheme. As opposed to running, where knee and ankle joint operated in phase, in walking the rebounding behaviour of the leg was distributed over the contact starting with the knee joint and followed by the ankle joint. Consequently, the walking contact could be prolonged and was finalized by a rapid pre-swing through a combination of ankle extension and knee flexion (Fig. 1). In a study on muscle function in human walking, Ishikawa et al. [3] showed that the elastic recoil within tendinous tissue of the gastrocnemius muscle at the end of stance is similar to an elastic catapult mechanism. In general, a catapult is released quickly to accelerate a small mass from its resting state using mechanical energy. Our results demonstrate a catapult-like acceleration at the ankle joint in walking but not in running (Fig. 2). Therefore, the globally described leg function based on spring-like mechanisms must be realized in different ways for walking and for running. The interplay between elastic leg structures and leg segmentation is dependent on the selected gait and needs to be understood in greater detail. Here an inverse dynamics approach could help to get insight into phases of joint elasticity.
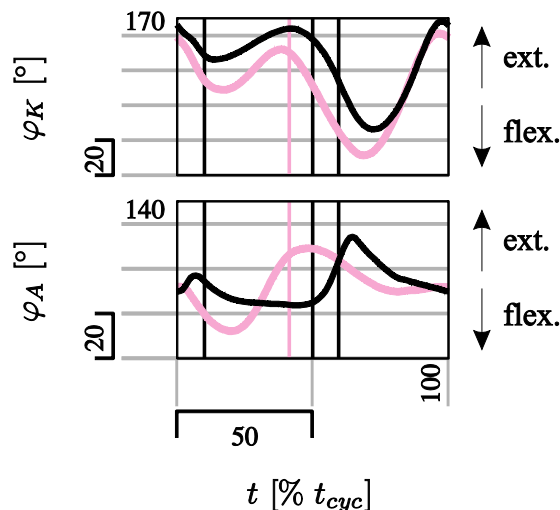

Fig. 1: Knee and ankle angles during walking (black) and running (red) at 1.6 m/s. Contact information is denoted by vertical lines.
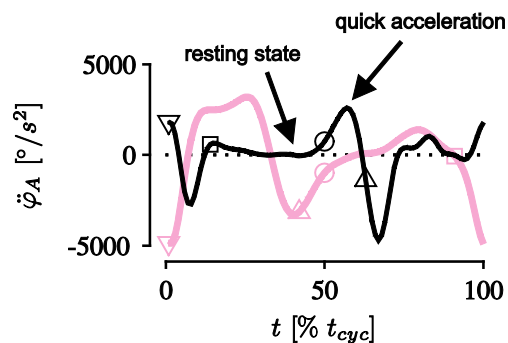

Fig. 2: Angular acceleration of the ankle joint during walking (black) and running (red) at 1.6 m/s. Contact information is denoted by $\triangledown$ (touch-down), $\triangle$ (take-off), $\square$ (contra-lateral touch-down), and $\circ$ (contra-lateral take-off).

REFERENCES

1. Geyer H, et al. *Proc R Soc B* **273**, 2861-2867, 2006.
2. Srinivasan M and Ruina A *Nature* **439**, 72-75, 2006.
3. Ishikawa M, et al. *J Appl Physiol* **99**, 603-608, 2005.