Roll-over Characteristics of Walking on Ramped Surfaces

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Introduction: Rocker-based inverted pendulum walking models (Gard and Childress, 2001) and empirical findings from human walking (Hansen, 2002) suggest the importance of maintaining an appropriate equivalent rocker shape of the ankle-foot system over a range of level-ground walking conditions. The purpose of this study was to examine the roll-over characteristics of the ankle-foot and knee-ankle-foot systems during single limb stance when walking on inclined surfaces. It was hypothesized that the effective rocker shape of the ankle-foot system would change in orientation to more appropriately interface with the walking surface, (Figure 1), making it easier for the person to walk with an upright posture.

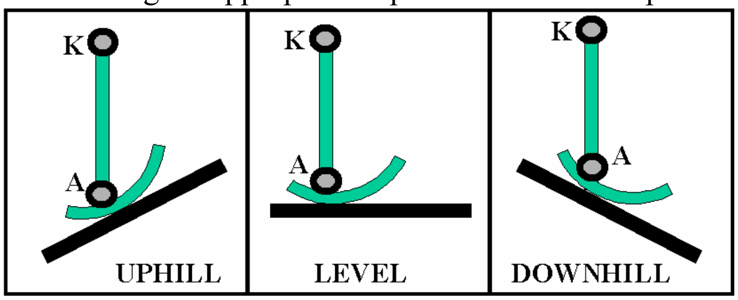

Figure 1 – Hypothesized changes in the effective ankle-foot rocker (A – ankle, K – knee markers).

Statement of Clinical Significance: Inclined walking can cause difficulties for persons using lower limb prostheses and/or orthoses. Information regarding the adaptations used by able-bodied persons when walking on ramps could be used to design prostheses and orthoses that can accommodate different terrain.

Methodology: A ramp capable of 5-degrees or 10-degrees of inclination was constructed and supported on both ends by force platforms. Using markers on the surface of the ramp and assuming static equilibrium of the ramp on the plates allowed for the calculation of the ground reaction force on the ramp and the center of pressure in the direction of forward progression (COP). Effective rocker shapes of the ankle-foot (AF) and knee-ankle-foot (KAF) systems of 10 able-bodied participants were found by transforming COP data into ANKLE-KNEE and ANKLE-HIP coordinates respectively (Figure 2). The transformation was applied only during single limb stance since the ramp was equivalent to a long force platform. The resulting effective rockers are truncated *roll-over shapes*, which are usually measured from heel contact to opposite heel contact (Hansen, 2002).

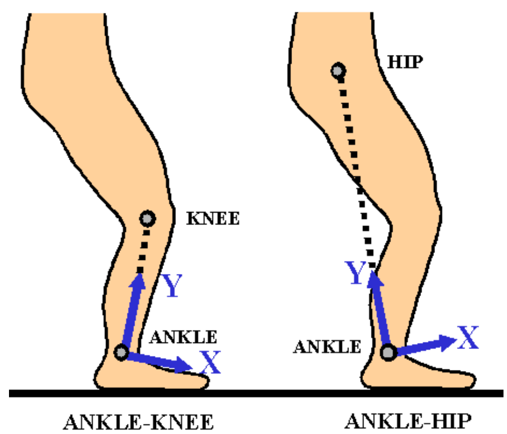

Figure 2 – Coordinate systems used to find the truncated AF and KAF roll-over shapes.

Results: The average truncated AF and KAF roll-over shapes for the ten participants are shown in Figure 3 for five inclination angles. The truncated AF roll-over shapes change in orientation when going from level to uphill inclinations but stay relatively constant when going from level to downhill walking inclinations, suggesting the hypothesis illustrated in Figure 1 is false. However, the truncated KAF roll-over shapes do change in orientation when going from level to uphill and when going from level to downhill inclination angles. Kinematics of the knee and hip were similar to those found by Wall et al. (1981).

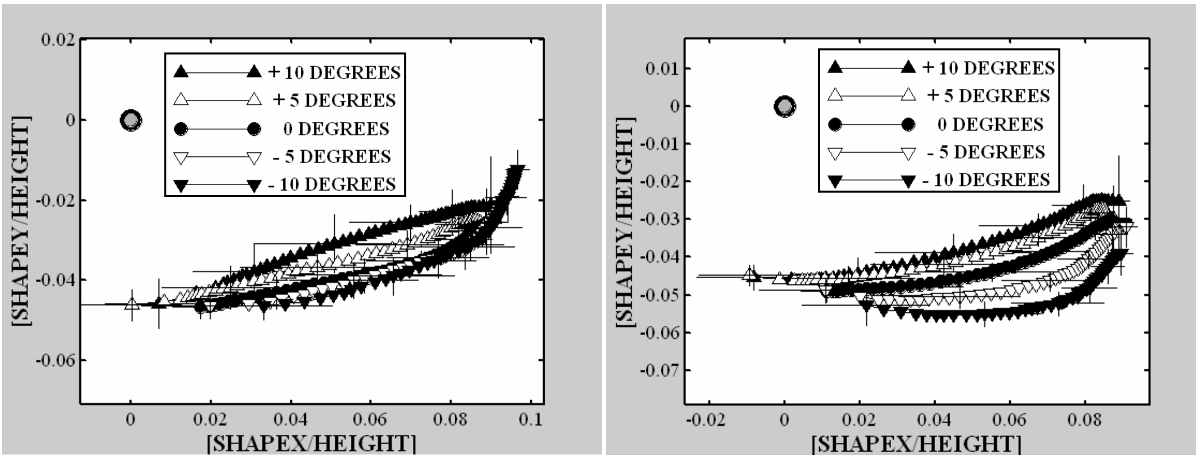

Figure 3 – Truncated AF (left) and KAF (right) roll-over shapes for different levels of ramp inclination.

Discussion: The results of the experiment suggest a revised hypothesis (Figure 4). A simplified model of inclined walking is that the ankle-foot system is the primary adapter when walking on the level and when walking uphill and that the knee is the main adapter when walking downhill. The knee appears to be important in downhill walking to shorten the trailing leg, allowing the next foot to contact before a "tipping" about the end of the foot occurs, and allowing the body to "keep on rolling" down the hill. The shortening of the stance leg in downhill walking would also presumably reduce the impact to the contralateral limb at heel contact (Wall et al., 1981).

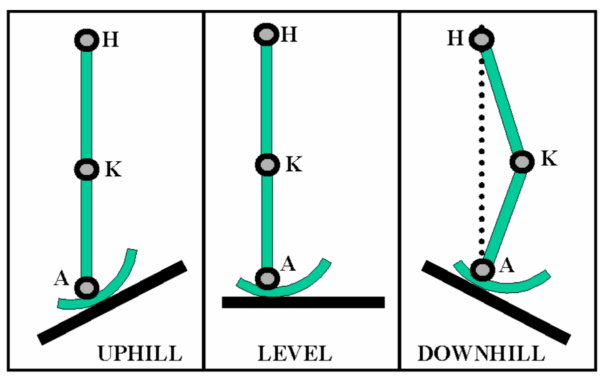

Figure 4 – Revised hypothesis describing the roll-over characteristics of the AF and KAF systems when walking on ramped surfaces. (A – ankle, K – knee, H – hip markers)

References:

Gard S. and Childress D. (2001) *Journal of Prosthetics and Orthotics* 13, 64-67.
Hansen A. (2002) *Ph.D dissertation*, Northwestern University.
Wall et al. (1981) *Ergonomics*, 24(10), 807-816.

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