KINETIC ANALYSIS OF GAIT UP INCLINED SURFACES

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Introduction

Walking on a level surface usually takes minimal effort and is a daily occurrence. Access to areas on different levels, however, may become a barrier to injured, elderly or disabled persons. Adding ramps or inclined surfaces is one means of permitting access to different levels in buildings. Little data are available concerning the efforts required to negotiate different incline gradients.

Purpose

This investigation quantified the moments of force and the work and power produced in the lower extremity during ascent of inclines of various gradients compared to those of level gait.

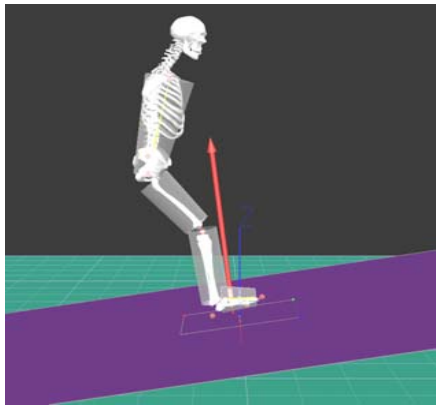

Figure 1 Subject ascending 9-degree incline. Vector is the ground reaction force.

Methodology

Twelve subjects (6 male, 6 female) between the ages of 20 and 30 volunteered. Sagittal plane kinematics from a 60-Hz digital video camera and ground reaction forces from a force platform (sampled at 240 Hz) placed on the ramp were collected. The participants ascended four different inclinations, five times each (level, 3-deg, 6-deg and 9-deg). The motion data were digitized using the APAS [1] and were then processed by the Biomech Motion Analysis System [2].

Results and Discussion

Figure 2 shows the ensemble averages of all subjects and each of the four incline conditions. The amplitudes were normalized to each subject's body mass and the abscissa was normalized to each condition's stride time from toe-off to toe-off. There was a significant decrease in stride length (p=0.055) with incline angle.

While the ankle had consistent patterns of the plantar flexor moment for all incline conditions, significant decreases for the work done at A1 (p=0.022) and increases for A2 (p=0.002) occurred as gradient increased. Increased work for the 6- and 9-deg conditions was partly due to reducing time spent doing negative work during midstance (A2).

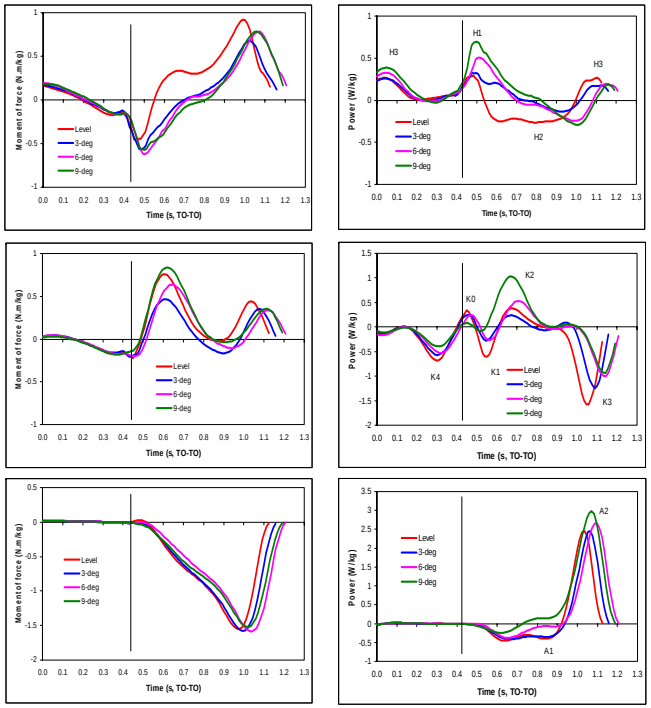

Figure 2 Grand ensembles of the ankle (bottom), knee (mid) and hip (bottom) moments of force (left) and powers (right) for each incline condition.

Results yielded few differences between the level and three-degree incline conditions but as the incline increased, concentric work by the ankle plantar flexors increased significantly by 78% at 9-deg slope compared to level while negative work decreased by 69%.

Similarly, at steeper inclines, the knee extensor moment (K2) showed significant increases (p=0.003) in concentric work during midstance with a 290% increase at 9-deg compared to level walking and less eccentric work (K3) around toe-off (43% less than level walking).

As for the hip flexors, there was increased concentric work at weight-acceptance (H1, p=0.005) and early swing (H3) especially for both the six- and nine-degree inclines as compared to level and three-degrees inclined gait. Compared to level walking, H1 increased 75% for the 6-deg incline and 300% for the 9-deg incline. During midstance, the inclined gaits typically required less negative work by the hip flexors (H2) than for level walking.

Conclusion

These results showed that there are only minor differences in the patterns of the moments of force of the lower extremity between level walking and walking at an angle of 3 degrees. This confirms the building code rule that permits indefinite lengths for ramps of 1:20 grade (2.9º). Furthermore, significant increases in work done by the ankle, knee and hip moments for 6- and 9-degrees inclines, make restrictions for ramps of these grades appropriate. In particular, inclines of 9-degrees were shown to greatly increase the work done by the knee extensors and hip flexors that could preclude persons with joint disabilities from negotiating these grades.

References

[1] Ariel Performance Analysis System, http://www.arielnet.com.
[2] Biomech Motion Analysis System, http://www.health.uottawa.ca/biomech/software.