The Contribution of Frontal Hip Power to Slope Walking

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INTRODUCTION

More than 30% of the older population aged above 65 in the USA fall at least once during a year [1]. The risk of falling in the elderly is increased when facing increased challenges to balance control while walking on uneven terrains such as up stairs and slopes [2]. The task demands for slope walking result in changes in lower limb kinematics and kinetics, but little is known about how power in the frontal plane changes with slope. During level walking, 23% of the total hip work is done in the frontal plane [3]. It is reasonable to expect that slope walking will place greater demands on the hip in the frontal plane to control the pelvis and trunk against gravitational forces in downslope walking, and to help lift the trunk in upslope walking. Therefore, the purpose of this abstract is to fully describe the change with the frontal of hip joint powers during slope ascent and descent, and to quantify total work done in the frontal of the hip joint.

METHODS

Nine healthy male adults (23.8±1.1years) were fitted with 29 retroreflective markers (Helen Hayes Marker Set). Each participant read and signed an informed consent form approved by the Institutional Review Board of Beijing Sport University. Participants were habituated to the walkway area and then performed at least three walking trials at each of seven grades (+20°, +12°, +6°, 0°, -6°, -12°, -20°). Each participant walked at a self-selected speed. Each subject took at least two steps on the slope before and after contacting the force platform. The kinect data and kinematic data were captured with a mounted force-platform (Kistler 9281CA, Switzerland) and an 8 camera 3D Optical Capture system (Motion Analysis Raptor-4, USA). Major gait events (heel strike and toe off) for each foot were visually identified. Kinetic data were filtered using a 4th order zero-lag Butterworth filter at 15 Hz [3].

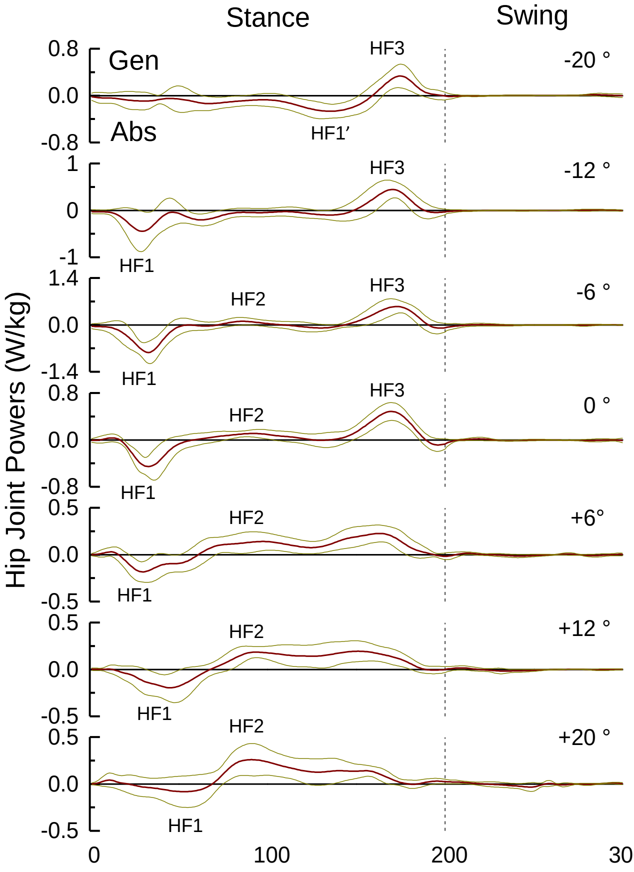

Figure 1: Frontal hip powers as a function of slope averaged for nine subjects.

The time integral of the power curves (i.e. work) was calculated (a) over one stride and (b) for each phase of the hip frontal power (HF1, HF2 and HF3; Fig. 1). The total work over the stride was the sum of the positive work and the negative work [4]. This paper focused on the comparisons within the upslope and downslope conditions (including level condition), but not between upslope and downslope. Thus, a one-way ANOVA was used to determine differences of hip frontal work within upslope and downslope, with Tukey post hoc tests; alpha level was set at 0.05.

RESULTS AND DISCUSSION

For energy absorption at early stance (HF1), significant differences were observed during upslope between 0° and 20° (p=0.04), and during downslope between 0° and -6° (p=0.02), and -6° and -20° (p=0.05). For energy generation during mid and late stance (HF2 and HF3), significant differences were observed during downslope between 0° and -20° (p=0.01, and -6° and -20° (p=0.03)) (Fig. 1).

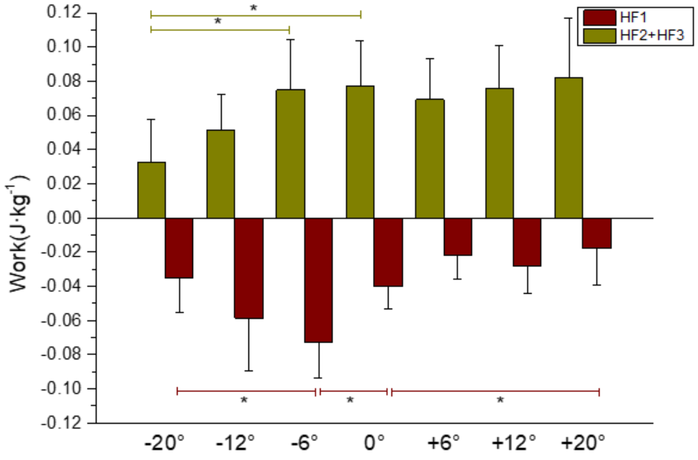

Figure 2: Average work for hip frontal power bursts. Asterisk (*) indicates p<0.05

During level walking, HF1 absorption is the eccentric control of the dropping pelvis during weight acceptance, and the HF2 and HF3 generation bursts raise the pelvis during midstance and push off phases [4].

During downslope walking, HF1 absorption increased for the -6 degree slope, but was not different from level walking for the steeper slopes (Fig. 2). The increased absorption at -6 degrees acts to control the dropping pelvis and was expected due to the greater downward distance traveled. Note HF2 generation during level walking becomes absorption (HF1′) in the most extreme slope (-20 deg., Fig. 1). HF1′ lasted from early stance phase to push-off phase; these the changes are consistent with higher demands associated with dropping pelvis. However, the work of HF1 was not greater than that during level walking (Fig. 1). The power phase HF2 generation decreased as expected, but only in the most extreme slope (-20 deg., Fig. 1). Overall, to accomplish downslope walking, relative to level walking, there was more energy absorption on the -6 degree slope, after that, energy absorption was decreased, and less energy generation in the hip frontal plane allows the pelvis and trunk to drop.

During upslope walking, HF1 absorption decreased as expected, but only in the most extreme slope (+20 deg., Fig. 2). It is interesting to note that the power phases HF2 and HF3 become one phase with increasing gradient (Fig. 1). The combined power bursts were consistent with higher demands associated with raising the pelvis to accomplish upslope walking. However, the total combined work of HF2 and HF3 was not greater than during level walking (Fig. 2). Overall, to accomplish upslope walking, relative to level walking, there was less energy absorption and similar energy generation in the hip frontal plane to elevate the pelvis and trunk.

CONCLUSIONS

To accomplish upslope walking, less energy absorption in the hip frontal plane was required, for downslope walking, less energy generation was required, but more energy absorption was required on -6 degree. The power bursts changed when facing different gradient slopes, indicating complex strategies to accomplish these locomotor tasks. Further research should examine other joint powers and compare upslope and downslope in order to gain insight into causes of stumbles, slips and falls. These observations could be used to improve design of biped robots and prosthetic devices.

REFERENCES

1. Chang et al. *JAMA*. 303(3): 288-288. 2010.
2. Honeycutt Ramsey. *Geriatr Nurs*. 23(5):250-257. 2002.
3. Hong, et al. *Gait Posture*. 42(4):523-528. 2015.
4. Eng Winter. *J Biomech*. 28(6):753-758. 1995.