INTRODUCTION
In an effort to minimize the risk of tripping during obstacle crossing, healthy subjects increase toe-obstacle clearance from an average of 3 cm during unobstructed walking to approximately 10-15 cm for various obstacle heights [1,2]. The hip, knee and ankle joints of the swing limb are modulated for phase and amplitude of flexion to ensure appropriate elevation of the swing foot over the obstacle [4]. Range of motion in the hip and knee during obstacle crossing is substantially greater than in the ankle, and it is reasonable to assume that coordination between these two joints should have the greatest influence on toe-obstacle clearance. The purpose of this study was to determine if the leading and trailing limbs utilize the same joint coordination strategy to cross obstacles of varying heights. It was hypothesized that the leading limb would exhibit greater hip flexion compared to the trailing limb. Secondly, it was hypothesized that an invariant pattern of joint coordination exists for each limb, independent of obstacle height.

CLINICAL SIGNIFICANCE
Inability to coordinate motion of hip and knee joints may result in obstacle contact, thereby increasing the risk of tripping and falls. Analyzing normal patterns of joint coordination will provide a better understanding of the natural timing and function of these joint motions. This information may eventually serve as a normative baseline by which to compare the progress of patients with joint pathology, or of those in post-surgery rehabilitation.

METHODOLOGY
Six healthy young adults (mean age, 24.8 years) were recruited for this study. Whole body kinematic data were collected using a six-camera HiRes™ system (Motion Analysis Corp., Santa Rosa, CA) during unobstructed walking and when stepping over an obstacle of height corresponding to 2.5%, 5%, 10%, or 15% of the subject’s body height (BH). All trials were conducted at a comfortable self-selected walking speed while barefoot. The order of obstacle height was randomly selected. Flexion angles of the hip and knee joints were plotted one against the other, from toe-off to heel-strike for each limb. A slope was calculated to represent the trend of joint coordination for each limb (Fig. 1). A one-way ANOVA with repeated measures for obstacle height was used for each limb to determine the effect of obstacle height on coordination of the hip and knee.

RESULTS
Coordination of hip and knee flexion during obstacle crossing was found to be consistent across all heights in the trailing limb, but not in the leading limb. The trailing limb showed a joint coordination slope of 0.178 ± 0.07 during level walking, and an average slope of 0.247 ± 0.06 across all obstacle heights (Fig. 2a). During level walking, the joint coordination slope of the leading limb was 0.184 ± 0.09, and increased from a slope value of 0.447 ± 0.09 for the lowest obstacle to a value of 0.602 ± 0.06 over the highest obstacle (Fig. 2b). As obstacle height increased, leading limb joint coordination was significantly altered due to a greater rate of increase in hip flexion, compared to the knee (p=0.001).
DISCUSSION

Patla et al. [4] showed that coordination of lower extremity joint motion in the swing limb is adjustable and modulated to successfully elevate the foot for safe obstacle crossing. The primary findings of this study indicate that trailing limb joint coordination remains invariant regardless of obstacle height, with foot elevation being achieved primarily through knee flexion [2,3]. Furthermore, current results indicate that as obstacle height increases, the leading limb increasingly relies on hip flexion to achieve appropriate limb progression and elevation. Understanding the coordination between hip and knee joints in response to different obstacle height may provide insights into the mechanism of tripping in individuals with joint disease or age-related declines in hip and knee range of motion.

REFERENCES


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