Urban terrain causes ankle end ranges of motion to be reached

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Summary

The effects of a cross-slope, often found in urban environments, on the inversion and eversion angle of the ankle during walking were determined. Cross-slopes can prove difficult for people with lower limb pathologies to traverse. Ankle end range of motion was reached for 8° and 10° slopes, with walking speed having an effect on these angles.

Introduction

Walking on a cross-sloped surface is common in urban environments and can be challenging for individuals with ankle injuries or pathologies. A cross-sloped surface is sloped perpendicular to the direction of walking, and often is used to aid water drainage.

Guidance from the UK Department for Transport [1] informs pedestrian infrastructure design to ensure sufficient access for disabled people. The guide advises a preferred cross-slope between 0.57°-1.15° up to a maximum of 1.43°. However cross-slopes can be found up to 8°, which is more than five times the recommended maximum slope [2].

Healthy ankle inversion and eversion (IE) ranges of motion are 5.0° ± 0.6° and 15.2° ± 1.0°, respectively, with ranges for fused ankles reducing to 3.5° ± 0.2° and 10.9° ± 1.0° [3]. The aim of this study was to determine the effect of cross-slope angle on ankle IE motion.

Methods

Sixteen healthy participants (7M, 9F) walked back and forth four times over cross-sloped platforms (0°, 2°, 4°, 6°, 8° and 10°) at a self-selected speed. For the 10° condition, slow and fast walking paces were also tested. Vicon (Oxford, UK) was used to record the motion of retroreflective markers affixed to the right leg and foot. Both upslope foot and downslope conditions were assessed.

The IE angle of the ankle at mid-stance, defined as the middle frame of stance phase, was calculated and averaged for each participant for the upslope and downslope conditions for each cross-slope angle. Shapiro-Wilks tests and a one-way repeated measures ANOVA were used to test for normality and compare between slope angles ($p < 0.05$).

Results and Discussion

All cross-slopes for both the upslope and downslope conditions resulted in changes in IE angles when compared to level walking ($p < 0.002$). The downslope condition caused inversion to occur, whilst the upslope condition resulted in eversion (Figure 1).

A faster walking speed increased inversion for both the up and downslope foot ($p < 0.018$). The slower walking speed increased eversion for both cases ($p < 0.001$).

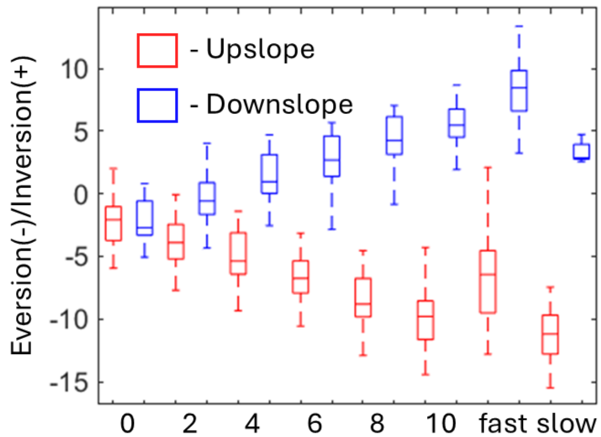

Figure 1: Effect of platform angle and walking speed on ankle inversion and eversion.

Participants used the end ranges of motion when walking on a 10° cross-slope, particularly when walking at a different speed to their natural pace. For patients who have undergone ankle joint fusion and do not have sufficient mobility to traverse these slopes, compensatory motions would be necessary. People with ankle pathologies are likely to walk more slowly than healthy individuals [4]. The increased eversion this causes should be considered.

Conclusions

Cross-slopes are very common in urban environments and are easily found to be greater than planning regulations permit. These cross-slopes can require individuals to use the end range of motion of the ankle to traverse them. Varying speed when walking also affects the ankle range required.

Acknowledgments

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