Approach path angle affects adaptive control of obstacle negotiation in humans

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Summary

The approach path angle at which an obstacle is encountered during walking affects the gait adaptations required for successful foot clearance. We investigated how healthy adults modulate their gait to step over obstacles from varying approach angles. Both lead and trail leg kinematics were affected by approach path angle and by whether the 'inside' or 'outside' leg initiated the crossing step. A behavioural preference to lead with the 'inside leg' was observed, with corresponding advance regulation of approach foot placements. Our findings provide insight into anticipatory gait control strategies and have implications for falls risk in balance-impaired populations.

Introduction

Understanding how humans and other animals adapt their gait to negotiate obstacles and uneven terrain is key to understanding locomotor control strategies for complex 'real world' environments. Obstacles are often encountered at oblique angles to the approach path - for example, people step sideways off kerbs, enter staircases from the side, and cross household obstacles at an angle [1]. However, previous lab-based studies of obstacle crossing kinematics have tended to use perpendicular approach paths, where the direction of travel is exactly at right angles to the edge of the obstacle [e.g. 2,3]. Simple models can be used to demonstrate that the different constraints and asymmetries introduced by taking an oblique path over the obstacle would be expected to alter movement strategies and/or swing phase leg trajectories. Understanding which behavioural and mechanical degrees of freedom are used to enable obstacle negotiation under these constraints would provide insight into control strategies and task goals for adaptive gait, as well as identifying high-risk crossing behaviours that may put people at risk of falls. Thus, the aim of this study was to experimentally investigate the adaptive control strategies used by healthy adults to step over obstacles from oblique approach angles.

Methods

Ten healthy participants (aged 21.6±1.78 years) with no musculoskeletal or neurological impairments repeatedly walked over a raised bar obstacle of height 17 cm oriented at -45°, +45° or perpendicular to the approach path (Figure 1). Obstacle orientation and start distance from the obstacle were randomised for each trial. The preferred lead leg was recorded for each orientation and trials were collected for both right and left lead leg crossings ('inside' and 'outside' lead leg for the -45° configuration; vice versa for the 45° configuration). Whole body kinematics and kinetics were captured using 3D optical motion capture (Vicon Motion Systems Ltd., UK).

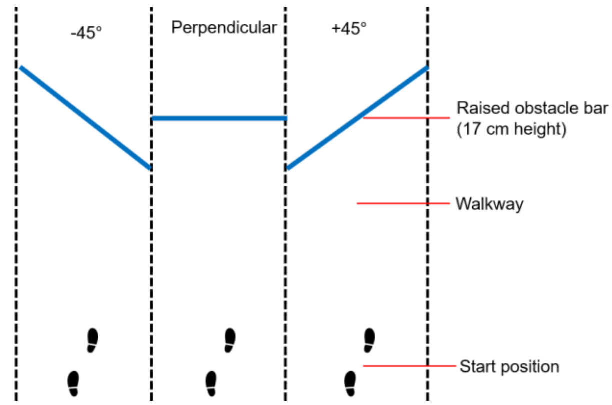

Figure 1: Experimental design. Three obstacle configurations were presented in a randomised order

Results and Discussion

Both lead and trail leg kinematics were affected by whether the 'inside' or the 'outside' leg was used to initiate the stride over the obstacle when it was approached from an obliquely angled path, in contrast to the symmetry observed for approach paths perpendicular to the obstacle edge. Correspondingly, participants adapted their gait to regulate foot placement during oblique approaches in order to initiate the crossing with a chosen lead leg, preferentially selecting the 'inside' leg to initiate the step over the obstacle (p = .02). An overall effect of approach path obliquity on swing phase kinematics was also found for both legs, independent of the direction of approach path offset: Trail leg peak ankle dorsiflexion velocity was greater for non-perpendicular approach paths (p = .03; Figure 1) whilst lead leg peak knee flexion angle and angular velocity were smaller for non-perpendicular approaches (p = .04; p = .03). The observed behavioural preferences and multi-joint kinematic adaptations highlight the biomechanical adjustments required to maintain stability and clearance, providing insight into adaptive control mechanisms for negotiating obstacles in real-world environments. Future work should investigate implications for falls risk in balance-impaired populations.

Conclusions

Our findings show that approach path obliquity influences obstacle crossing strategies, highlighting the importance of adaptive gait control for maintaining stability and foot clearance in real-world environments.

References

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