How does increased slip and fall risk influence locomotion in turning maneuvers?

Tyler D Whitacre[1], Hannah Goldsmith[2], Christian M Hubicki[3], Monica A Daley[1,2]

[1]*Ecology and Evolutionary Biology*, University of California, Irvine, Irvine, CA, USA

[2]*Comparative Biomedical Sciences*, Royal Veterinary College, Hatfield, Hertfordshire, UK

[3]*Mechanical Engineering*, Florida State University, Tallahassee, FL, USA

twhitacr@uci.edu, hgoldsmith918@outlook.com, chubicki@fsu.edu, madaley@uci.edu

Summary

Speed and stability in turning maneuvers can be important for predator evasion and injury avoidance. We investigated the dynamics of turning maneuvers in guinea fowl. To investigate locomotor priorities, we compared turning maneuvers in high *versus* low friction terrain. Slips and falls occurred frequently on low friction terrain; yet did not lead to pronounced shifts in locomotor strategy. Some birds fell frequently and did not learn to avoid falls. Other birds always avoided falls. This suggest that fall avoidance may not be equally important to all individuals. Some birds opted for paths that minimized distance travelled and turn angle, suggesting minimal effort as a priority. Individual variation in risk perception and risk tolerance appear to be important factors in non-steady maneuvering strategies.

Introduction

Navigation through natural environments requires balance of many task-level performance demands, including speed, economy, stability and injury avoidance. We are interested in how animals adapt their locomotor strategies over both short and long timescales depending on task-level performance constraints and priorities. Prior work has revealed that guinea fowl are able to maintain stability and recover rapidly from terrain height perturbations using relatively simple intrinsic mechanical control strategies [1-2]. However, less is known about how guinea fowl plan and adjust locomotor behavior over multiple step maneuvering tasks, which are likely to be planned and optimized over longer timescales compared to disturbance rejection tasks.

Here we investigated task-level performance priorities by measuring guinea fowl locomotion in straight runs and turning maneuvers, on high and low friction substrates. Based on simple point-mass models of turning locomotion [3-5], we expected slippery terrain to lead to a shift in control priority to minimize horizontal forces and maintain a higher ratio of vertical to horizontal force for slip avoidance. Strategies to achieve this include slower speed, shorter steps and shallower turn angle — more closely approximating a large radius circular path [5].

Methods

We measured guinea fowl locomotion in 4 runway conditions: control straight (CS) slippery straight (SS), control turns (CT) and slippery turns (ST), with 10-20 repeated trials per condition (N = 7 individuals). Slippery terrain was created using polypropylene, after Clark and Higham [6]. Turns were executed in a 90-degree bent runway, wide enough to allow variation in path and turn sharpness as a control strategy.

Results and Discussion

We found that guinea fowl used surprisingly similar turn strategies in high and low friction terrain, choosing paths that minimized turn angles in both conditions. Guinea fowl ran slower in turns compared to straight runs, on both high and low friction terrain. They did not slow down substantially more in slippery turns. Slips and falls occurred frequently for some birds on low friction terrain. Yet, they did not learn to avoid falls with repeated trials.

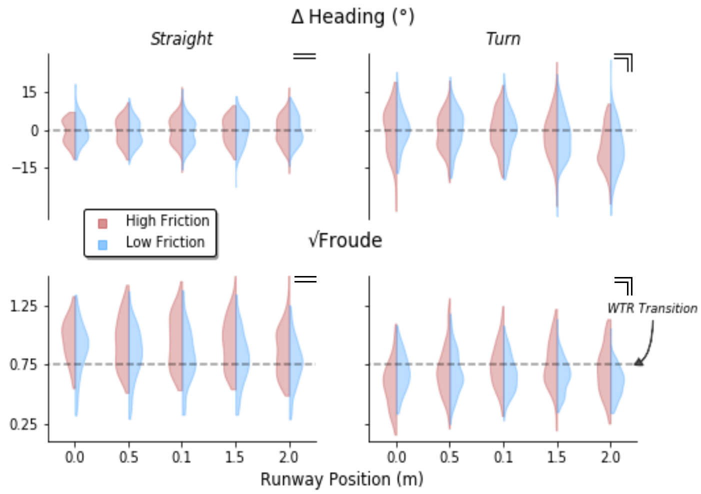

Fig. 1. Guinea fowl ran slower in turns compared to straight runs, but did not show substantially lower turn angle or speed when turning on low *vs* high friction terrain. Violin plots illustrate probability density distributions for change in velocity heading (top) and dimensionless velocity (bottom) at intervals of 0.5m along the straight runway (left) and turn runway (right).

The findings suggest that fall avoidance is not always a critical priority for guinea fowl. Some birds used paths that minimized distance travelled and turn angle, suggesting minimal effort as a priority. The findings could relate to motivational factors, such as laziness in absence of actual predator. In ongoing work, we are collaboratively developing a theoretical framework to predict maneuvering paths based on optimization to minimize cost, subject to probabilistic risk models and individual variation in risk perception and acceptable risk tolerance.

Acknowledgments: We thank Emily Sparkes and Jade Hall for assistance in data collection, and BBSRC UK for funding the experimental work.

References:

[1] Daley, MA & Biewener, AA (2006). PNAS 103:15681-15686.

[2] Blum, Y, Vejdani, HR, Birn-Jeffery, AV, Hubicki, CM, Hurst, JW & Daley, MA (2014). PloS one, 9: e100399.

[3] Alexander, RM (2002) Stability and manoeuvrability of terrestrial vertebrates. Int Comp Bio: 42: 158-164.

[4] Tan, H & Wilson, AM (2011) Proc Roy Soc B: 278: 2105-2111.

[5] Daley, MA (2016). In Understanding mammalian locomotion: concepts and applications, Ed. JEA Bertram. Wiley Blackwell.

[6] Clark, AJ & Higham, TE (2011). Slipping, sliding and stability: locomotor strategies for overcoming low-friction surfaces. J Exp Bio 214:1369-1378.