ADAPTATIONS OF GRASSHOPPERS TO JUMP FROM FLEXIBLE SUBSTRATES

[1]Yongjun Jung, [1]Minjung Baek, [1]Yongwoo Kim, [1]Eunjeong Yang, [2]Eunjin Yang, [2]Ho Young Kim, [3]Matthew J. Klassen, [3]James M. Moeller, [4]Hang-kyo Lim, [1,5]Sang-im Lee, [1]Piotr G. Jablonski

[1]*Laboratory of Behavioral Ecology and Evolution, School of Biological Sciences, Seoul National University, Seoul 08826, Korea.*
[2]*Department of Mechanical and Aerospace Engineering, Seoul National University, Seoul 08826, Korea.*
[3]*St. Catherine University, 2004 Randolph AVE, St. Paul, MN 55105, USA*
[4]*Notre Dame University of Maryland, 4701 North Charles St, Baltimore, MD 21210 USA*
[5]*Institute of Advanced Machines and Design, Seoul National University, Seoul 08826, Korea.*

Abstract

Grasshoppers have become model organisms to understand the biomechanics of jumps. However, surprisingly little is known about their adaptations to the natural substrates from which they normally jump off. Stems and leaves of plants are flexible, while every analysis of jump biomechanics are from solid substrates.

Here we tested the jump performance of one ground-dwelling grasshopper species, *Oedaleus infernalis*, and two plant-dwelling grasshopper species, *Atractomorpha lata* and *Acrida cinerea,* to determine morphological and behavioral characteristics that may be adaptations to efficiently jump off the flexible substrates. Based on over 700 filmed jumps we analyzed the jumping performance differences between species from one fixed substrate and five experimental substrates that differ in the degree of flexibility and vibrational frequency.

We hypothesize that longer legs, longer jump duration and deeper substrate push are all adaptations to jump off the flexible substrates such like stems and leaves.

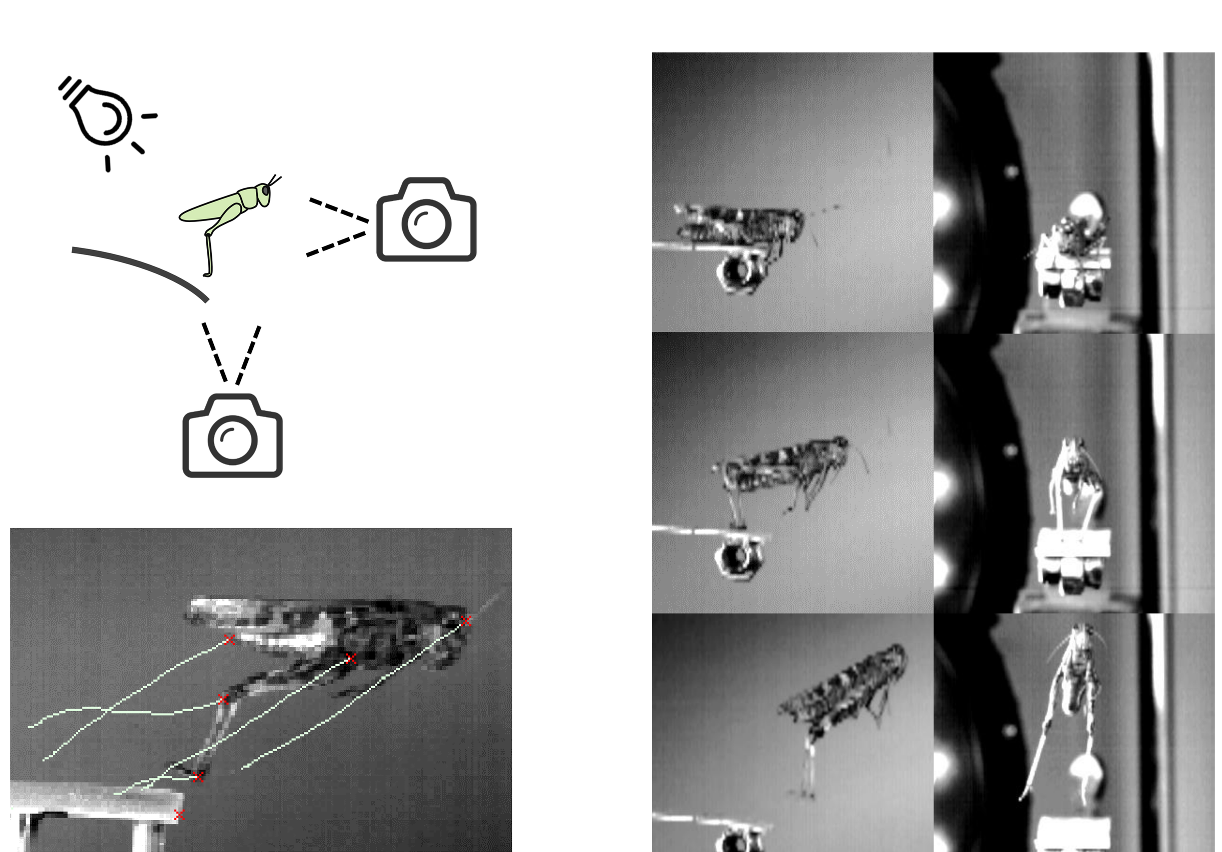
Introduction

Each grasshopper have very distinct niche and characteristics. *Atractomorpha lata* (Fig. 1 left) lives on the grasses while *Oedaleus infernalis* dwells on the ground. As the niche differs, the jumping performances of each species have adapted to its own environment. In this study, we focused on two species, *A. lata* female and *O. infernalis* male, since those two classes have similar body mass.

Fig. 1. *Atractomorpha lata* (left) usually lives on the grasses. Unlike *A. lata*, *Oedaleus infernalis* (right) prefers ground. Even the color of each species reflects their environments.

Materials and Methods

Grasshoppers were captured from Soreapogu ecological park. They were kept in a transparent acrylic cage and were fed with lettuce. Thin PVC plate were cut into one fixed and five flexible substrate with different flexibility and vibrational frequency. Each individual was tested jumping from each substrate. Grasshoppers were allowed to jump only two substrates a day. Order of substrates was randomized. Every jump was filmed with TS1000ME 1000fps high speed camera from side and front. The video was analyzed with MaxTRAQ tracking the motion of the grasshoppers.

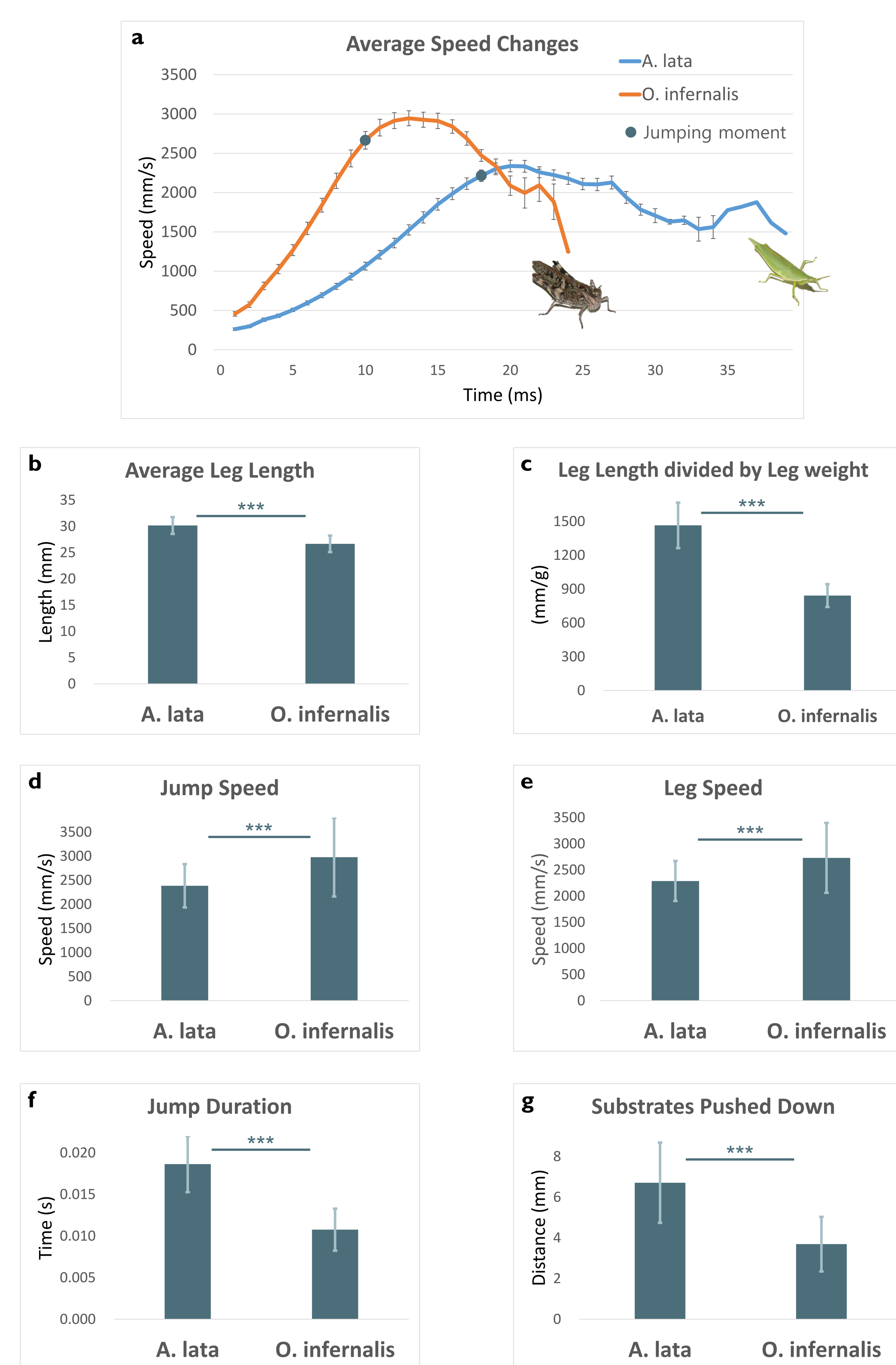


F (upper lef
MaxTRAQ (lower left). Jumping moment of the grasshopper from side and front camera (right).

Results

After digitization, we calculated each grasshopper's speed, acceleration, time taken until jump(jump duration), jump angle, leg angle and etc. T-test was used for the statistic analysis. The jump performance was different between species. However, it was similar among substrates for the same species. Here, in this graphical presentation we average all the data for each species (from all substrates).

O. infernalis had higher speed, acceleration and faster jump duration (**a**). *A. lata* had slightly longer legs than *O. infernalis* (**b**). However when the leg length was divided by its leg weight, *A. lata* had much longer legs compared to its leg weight indicating relatively smaller muscles (**c**). Speed at the moment of jump was higher from *O. infernalis* (**d**). Leg speed pushing the substrates down was also faster from *O. infernalis* (**e**). It took about twice longer time for *A. lata* to jump from substrates (**f**). The distance flexible substrates pushed down was about twice longer from *A. lata* (**g**).



Conclusion and Discussion

O. infernalis jumps very quickly and the speed is also faster than *A. lata*. In contrast, *A. lata* has longer jump duration and more substrate push.

For the grasshoppers that live on the ground, *O. infernalis*, the leg movement immediately comes back as a propulsion. Since fast escape from a predator increases their survival rate, they would have developed quick and fast jumps.

However when the grasshoppers live on the grass, *A. lata*, the substrate fluctuates and the leg movement doesn't make immediate propulsion. Grasshoppers would have to push more to get enough energy to jump. Therefore grasshoppers on the grass would have developed longer legs, longer substrate push and longer jump duration.

Next analysis will be focused on *Acrida cinerea* which is the most grass adapted grasshopper. We will evaluate the hypotheses that longer legs and less steep inclination of trajectory as well as less steep angle of line of force are all adaptations to efficiently jump off the flexible substrates.