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Improving accuracy and avoiding bias when estimating true maximal sprint performance in the Western Fence Lizard (*Sceloporus occidentalis*)

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INTRODUCTION

Whole-organism performance traits include any quantitative measures of how an organism performs at an ecologically relevant task. For Western Fence Lizards (*Sceloporus occidentalis*), sprint speed is a key measure of whole-organism performance because it is positively correlated with fitness with respect to both natural selection (survivorship) and sexual selection (reproduction) (Lailvaux and Irschick 2006). Knowing when an individual uses their maximal performance provides insight into what selective pressures are acting on that specific trait because an organism is expected only to use their maximal performance capacity when advantageous for their overall fitness (survival and reproductive success) (Meyers and Irschick 2015). Thus, maximal sprint performance is often studied in *S. occidentalis* and many other species to further investigate questions related to an organism's fitness in their natural environment.

RESEARCH QUESTION

Many studies researching maximum sprint performance have found that estimating maximum sprint speed with a limited number of trials significantly underestimates an organism's true maximal performance (Adolph & Pickering 2008). This is because overall repeatability is low due to lack of consideration of within individual variation from having too few trials per individual. One remedy would be to increase the number of sprint trials, but in ecological studies this often is not possible given limited sample sizes of organisms. In this study, we examined how within individual variation and per individual trial size affect the statistical estimation of maximal sprint performance. The goal of the project was to describe variance within sprint trial data and offer suggestions for more accurate methods of estimating true maximal sprint performance in ecological studies. We sprinted a population of 26 individual lizards and determined statistical repeatability and variance both within and among individuals.

We hypothesized that 1. overall repeatability would be low and non-significant and 2. within individual variance would be higher than among individual variance.

METHODS

- Individuals were captured and marked by toe clippings (permanent identification) and paint markings (visual identification from a distance)
- Measured snout to vent length (body size) (Image 1) and mass for each individual lizard
- Exact capture locations were documented to ensure release was in their home range

Sprint Trials:

- Individuals were recaptured and incubated for 1 hour at 35°C (optimal temperature for sprinting) prior to each sprint trial
- Individuals were only sprinted 2-3 trials per day to allow for adequate rest time
- Individuals were placed on one side of the racetrack and tapped lightly on their dorsal side to initiate sprinting
- Infrared photocells spaced every 12cm along the racetrack detected motion when the lizard sprinted by
- The fastest split between photocells was considered the individual's maximum speed for each trial
- Each lizard was sprinted between 2-11 trials total

Data Analysis:

We calculated the within- and among- sample sums of squares and variances using an ANOVA with the lizard ID as the main effect (JMP software). We calculated repeatability following the equations found in Lessells & Boag (1987).

Image 1. Snout to vent length being measured on a male Western Fence Lizard

Image 2. Western Fence Lizard with color-coded paint markings for visual identification

RESULTS

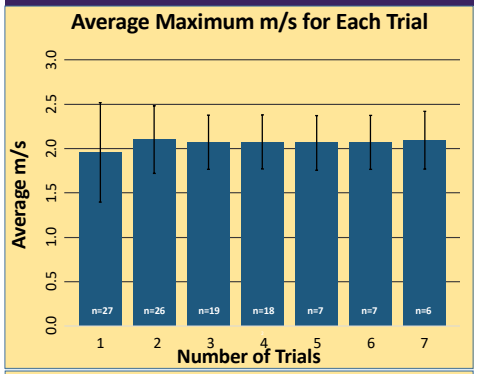

Fig. 1: mean sprint speed (m/s) across a sample of 26 lizards. As the number of trials increased, sprint speed slightly increased. Among individual variance (bars) also decreased as trials increased.

- 26 individual lizards were sprinted between 2 and 11 trials to reach a total of 115 sprint trials for the population. Speeds ranged between 0.551 m/s for the slowest and 3.846 m/s for the fastest 12cm splits.
- Within individual variance was 0.151 whereas among individual variance was 0.062. Thus, there is more variation within an individual than among individuals. Lizards have substantial variability in when they choose to run fast vs. not run as fast.
- Repeatability was 0.29, which is low but moderately repeatable (Harper 1994).
- Despite being somewhat low, repeatability was significant ($F = 2.76$, df = 25,87, p = 0.0003).
- Despite high amount of intra-individual variation in sprint speeds, with enough trials there is significant repeatability, and therefore reliability, in results.

CONCLUSION & DISCUSSION

Maximum sprint performance is an important measurement when studying whole organism performance traits. However, in order to avoid biased conclusions, it is important to understand the amount of variance not just among your study subject, but also within them. For example, some individuals may vary widely in how fast they run whereas other individuals may sprint very consistently. If a researcher were to use only maximal values without quantifying this variation, they may not accurately draw conclusions about sprint performance. Without an accurate estimation of true performance, all proposed results and conclusions are inherently inaccurate and biased. Thus, it is important to know how to most accurately estimate true maximal speeds for specific study specimens.

This study specialized in determining more accurate procedures for estimating maximal sprint speed in Western Fence Lizards (*S. occidentalis*). Our results confirmed that sprint speed in lizards has low repeatability. However, our data help us reject the second part of hypothesis 1 (that repeatability was not significant). Hypothesis 2 was confirmed as there was more variation within an individual (0.151) than among individuals (0.062). Ultimately, because overall repeatability was relatively low (0.29), choosing a higher sample size of sprint trials at the expense of a lower number of individuals will yield slightly more precise estimations of the true maximum speed, ultimately decreasing bias (Adolph & Hardin 2007).

Based on our results and results from other studies, we recommend that studies on ecological performance avoid using pure maxima for analyses; doing so underestimates true maximal performance, especially when there is significant intra-individual variation and low repeatability. We recommend that researchers first quantify repeatability, intra- and among- individual variance, and use other measures such as quantiles (Head et al. 2010) or sample means to most accurately quantify ecological performance

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