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Measuring the Relationship Between Body Condition and Body Composition in Two Kansas Spider Species

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ABSTRACT

Energy is stored by organisms in one of three forms: proteins, carbohydrates, or lipids. This energy is used to perform the actions necessary for an organism to survive. An individual's body condition is a summary accounting for both the ability to acquire resources and properly allocate them. Ecologists use a variety of indices to estimate the body condition of an organism. In this study, two species of Kansas spider were caught in the wild and analyzed for body composition and body condition. These spiders have two distinct foraging types; one being a web-builder, *Neoscona crucifera,* and the second a ground/active hunter, *Rabidosa punctulata.* The body composition of these spiders differed as might be expected with two very different foraging styles. *N. crucifera* contained a higher fat content, and *R. punctulata* contained a higher percent protein and water weight by mass. The only significant relationship between a body condition index and a measure of any energy macromolecule was found between lipid percentage and the body condition residuals in *R. punctulata.*

Keywords: *Body condition, fitness, macromolecules.*

INTRODUCTION

It is important for animals of all classes to have the ability to store energy. The organism's overall health and fitness depends heavily on the allocation of these resources (Andersson, 1982). This definition illustrates a link between the concept of condition and an individual's energy reserves. Energy is stored in the accumulation of macromolecules like proteins, lipids, and carbohydrates (Garrett and Grisham, 2016). Proteins primarily function as enzymes and structural features in living organisms, but occasionally may be metabolized to extract energy. Lipids or fats are long-term, high-energy storage molecules used by an organism to keep excess energy for a period when resources are low. Carbohydrates are short and medium length energy molecules. Carbohydrate monomers like glucose are broken down right away to create energy. Long carbohydrate chains like starch, glycogen, and cellulose are used to store energy within a medium length period; the long chains can be clipped up into their monomers and quickly metabolized for energy (Garrett and Grisham, 2016).

Condition of an organism is a hypothetical concept that includes that individual's ability to acquire, store, and expend its nutritional resources. Individuals in good condition (high fitness) might ideally have excess amounts of these macromolecules stored in their body, while individuals in poor condition would have relatively lower fitness. Variances in condition are dependent upon two major factors. The first is the genotype of the organism; condition and fitness are widely influenced by many different locations in an organism's genome (Wilgers and Hebets, 2015). Genetic traits which effect things like foraging, mating, and learning all have an impact overall condition of an organism. Environment is the second factor condition is dependent upon. Availability of food and water, number of predators, and temperature may all play a role in the development of the concept of condition. The environment and the genotype of an organism interact in a complex manner as an individual makes decisions on resource allocation and acquisition, shaping each individual's unique condition (Wilgers and Hebets, 2015).

Often times, ecologists will use this connection to estimate the amount of energy reserves an animal may have by measuring the condition of the animal in some way or another (Andersson, 1982). One common way is to calculate some sort of proxy or body condition index. These measurements use some physical measurement of body size (something that doesn't fluctuate on a short time scale with recency of a meal) and mass (something that does fluctuate with meal size and frequency) to estimate condition. These body size indices are often easy to measure, which is why they are used as estimates to body condition and overall energy reserves (Jakob, Marshall, Uetz, 1996). Though this is a widely used and accepted way of estimating condition, it is not clear whether many of these body condition measurements actually give any indication of differences in excess energy storage. Factors that have nothing to do with energy reserves like bone or exoskeleton mass and water weight may be causing a difference in these measurements (Tomkins, et al, 2004). Many proxies and indices have been used in the past to quantify condition. Likely, the most widely used measurement of body condition is the body mass to body length or width ratio (Wilgers and Hebets, 1996). This utilizes a dynamic variable with resource acquisition in body mass, and a mostly static, especially in a short period of time variable in some kind of skeletal or exoskeletal length measurement (Jakob, Marshall, Uetz, 1996). Other methods are used specifically for one type or kind of animal. For example, ecologists interested in the condition of fish often use liver indices, body water content, visceral-somatic indices, calorific values of fish tissues, and several others (Bolger and Connoly, 1989). In research done on bears, morphometric measurements, blood analyses, chemical analyses of carcasses and fat content of bones and muscles have all been used to estimate condition (Cattet, et al, 2002).

Though these indices measuring condition are used frequently, little research has explored how accurate these indices are at predicting overall condition of an individual and estimating the energy reserves, that individual may or may not possess. We know that theoretical condition and the energy reserves of a specific individual may not be entirely dependent or dependent at all upon its body size, and that energy growth may occur independent of changes in body weight or size, therefore assumptions of condition based on body condition measures may or may not be accurate (Bolger, Connoly, 1989).

This study aims to find a connection between measures of energetic reserves and theoretical condition of spiders. Some spiders may store macromolecules in different ratios, depending upon their life and foraging styles. Spiders that hunt by sight, seeing and chasing their prey, are likely to store more of their reserves in carbohydrates for quick access. Spiders that use webs to capture prey may sit on their web for a week at a time waiting for their next meal. This would require long-term energy storage, and these spiders would likely store excess energy in fat molecules. Correlations such as these, between spiders of different foraging types and body composition and condition will be explored throughout this project.

Rabidosa punctulata and *Neoscona crucifera* are two species of spiders found in central Kansas. *R. punctulata* is in the wolf spider family and hunts mostly on the ground while the *N. crucifera* is a web building spider that sits and waits for its prey. Fat content will likely be higher in the *O.* weaver because it will need to store energy for a longer period of time than R. *punctulata.* By contrast, the protein and carbohydrate content of *R. punctulata* may be higher because they must be able to chase and catch prey requiring quick movements and quickly metabolized energy. We also anticipate that a higher body condition index will correlate with higher energy resources readily available.

MATERIALS AND METHODS

Spider samples of two species, *R. punctulata* and *N. crucifera* were caught in a grass field in McPherson, KS. About 90 spiders were captured by using headlamps at night, scanning the ground for reflections of the wolf spider's eyes and the trees on the edge of the field for orb weaver webs.

After the samples were caught, the mass was measured and recorded the next day. The samples were put in the freezer, and the width of the cephalothorax was taken with a pair of digital calipers. Three measurements were recorded for each spider and then the average of these measurements were taken.

The samples were transferred to labelled test tubes and put in an incubator at 60C to dry for three days. The samples were weighed and the dry mass was recorded.

To obtain a lipid quantity, the samples were soaked in 3mL of chloroform in a fume hood for 24 hours. They soaked in a test tube enclosed with a cap. Then the chloroform was poured off and 3mL of fresh chloroform was introduced. After another 24 hours the chloroform was poured off. The residual chloroform left in the test tube was allowed to evaporate off for another 24 hours. Then the samples were put back in the incubator at 60C to dry for another 48 hours. The mass of the samples without lipids was measured and recorded.

Proteins were extracted after the lipids were analyzed. The dry spider remnants were ground up individually using liquid nitrogen and a mortar and pestle. Then the powder was suspended in a solution of 0.1 M NaOH at a concentration of 2.0 mg of spider sample per 1.0 mL of NaOH. The solutions were shaken for 30 minutes at 230 rpm. Then heated in a water bath at 90C for 15 minutes. The solutions were centrifuged at 13,000 rpm for 10 minutes. 12.5 microliters of the supernatant was collected and mixed with 1.5 mL of Coomassie Blue Bradford Reagent. The absorbance was measured and compared to a standard curve to get concentration.

RESULTS

Average body mass was higher in *N. Crucifera* than *R. punctulata,* but there was much more variation between *N. crucifera* than between the *R. punctulata* group. Average mass for *N. crucifera* is 0.632g and for *R. punctulata* it is 0.223g ($P<.001$ $t=5.682$ $df=69$).

Table 1: Body compostion percentages of water, protein, and lipids in *N. crucifera* and *R. punctulata.*

Species	Water	Protein	Lipid
N. crucifera	71.7%	2.21%	3.83%
R. punctulata	73.2%	3.30%	2.36%

N. crucifera had a higher lipid percentage than *R. punctulata* 3.83% to 2.21% ($t=4.486$ $df=69$ $P<0.001$).

While, *R. punctulata* had a higher water percentage and protein percentage than *N. crucifera*. Water content of *R. punctulata* 73.2% and *N. crucifera* 71.7% ($t=-2.170$ $df=69$ $P=0.033$). Protein percentages of *R. punctulata* and *N. crucifera* 3.30% and 2.21%, respectively ($t=-10.227$ $df=69$ $P<0.001$).

To obtain a measure of body condition, mass vs. cephalothorax width were plotted and the residuals of this plot were taken (Figure 1 and 2). These values are what was used for a measure of body condition.

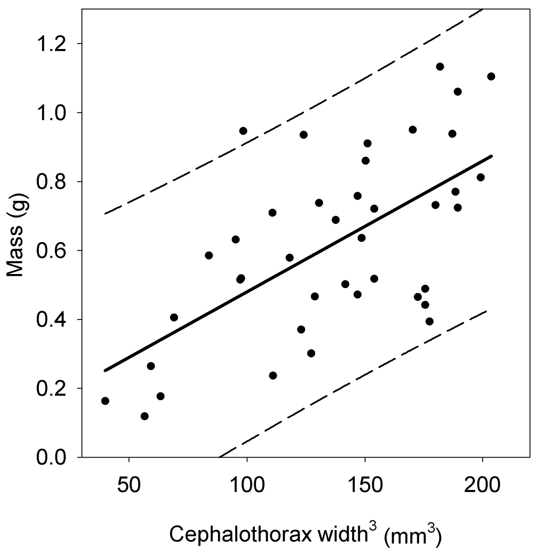


Figure 1. Regression of mass and cephalothorax width for *N. crucifera*. Residuals for body condition were taken from this plot.

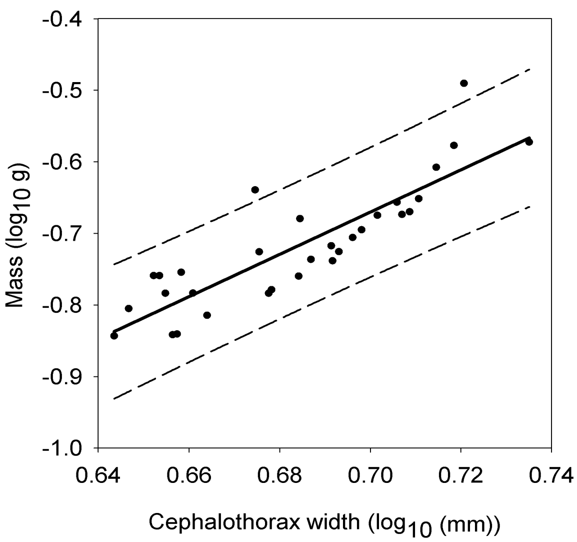
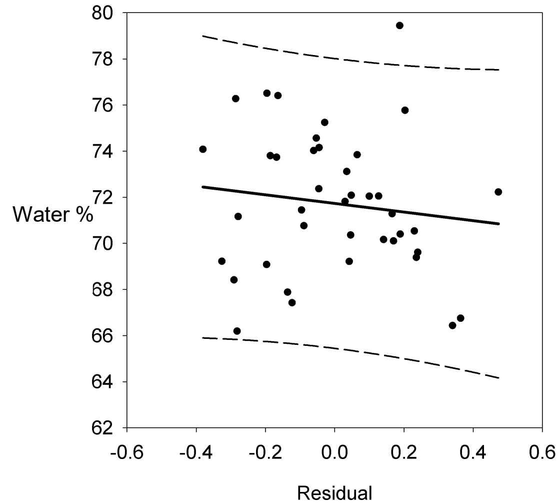
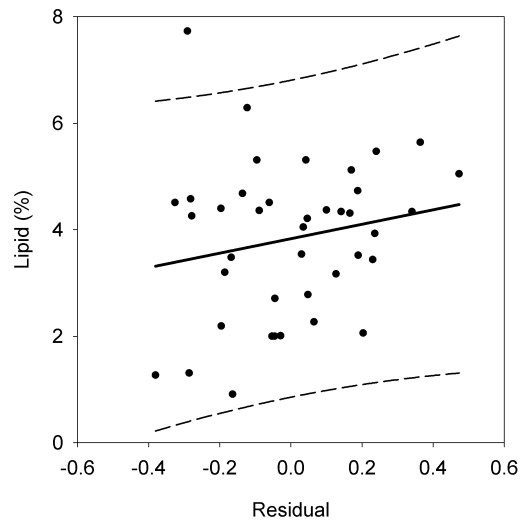


Figure 2. Regression of mass and cephalothorax width for *R. punctulata*. Residuals for body condition were taken from this plot.



Figures 3. *N. crucifera* body condition vs. water.



Figures 4. *N. crucifera* body condition vs. lipid.

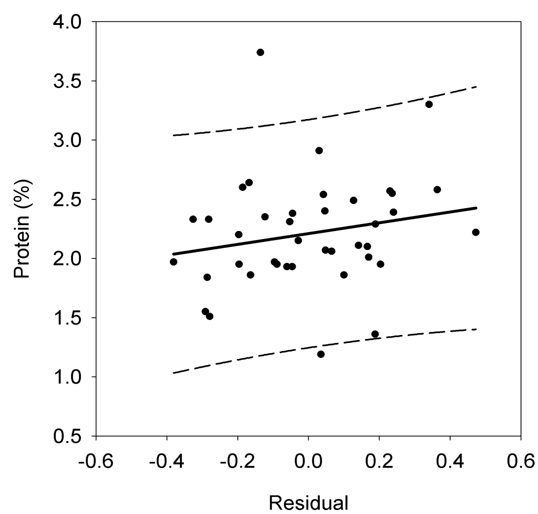
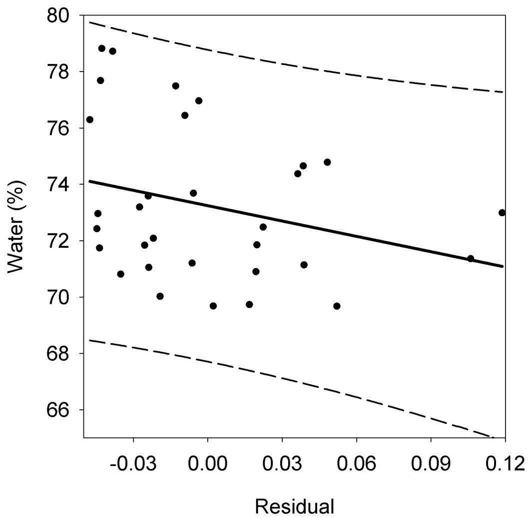


Figure 5. *N. crucifera* body condition vs. protein.

A linear regressions testing for correlation between *N. crucifera* body condition and water content found no significant relationship (Figure 3; R^2=0.016 df=38 P=0.435). Likewise, no relationship was found between body *N. crucifera* residuals and protein percentages (Figure 5; R^2=.040 df=38 P=0.217). Finally, a regression did not show any significant correlation between body condition residuals and lipid percentages in *N. crucifera* (Figure 4; R^2=0.037 df=38 P=0.234).



Figures 6. *R. punctulata* body condition vs. water.

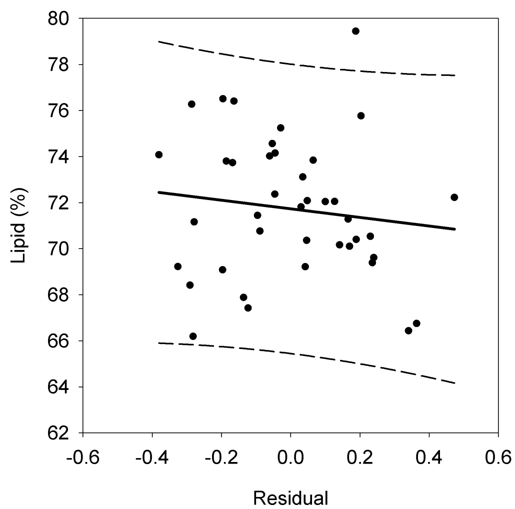


Figure 7. *R. punctulata* body condition vs. lipid.

A linear regression run on *R. punctulata* body condition residuals vs. protein and percentages did not indicate any significant correlation (Figure 8R^2=0.000 df=29 P=.982). A regression between body condition residuals and water content did not show any significant correlation (Figure 6; R^2=0.080 df=29 P=0.123). A linear regression run on the body condition residuals vs. lipid percentage did, however, show a significant correlation (Figure 7; R^2=0.227 df=29 P=0.007).

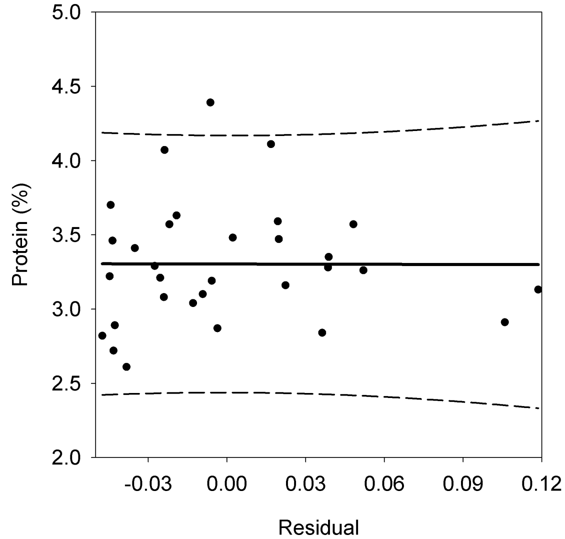


Figure 8. *R. punctulata* body condition vs. protein.

DISCUSSION

When comparing average mass between female *N. crucifera* and female *R. punctulata,* the average mass of *N. crucifera* was nearly three times larger than *R. punctulata. N. crucifera* and *R. punctulata.*

R. punctulata held a higher water content, containing about 1.5% more water on average. This could be explained by their lower lipid content as lipids are known to be hydrophobic.

R. punctulata also contained a higher protein percentage than *N. crucifera* by mass. *R. punctulata* is an active hunting spider and likely utilizes its muscle mass more than *N. crucifera* therefore it chooses to allocate more of its energy and resources to building more protein to allow it to hunt more effectively and overpower larger prey.

N. crucifera had an overall higher lipid percentage than *R. punctulata.* This is best explained by the need for *N. crucifera* to subsist for longer periods of time without food. Because lipids are long-term energy storage molecules, this is the best form to store it in for energy between meals.

Body condition residuals of *N. crucifera* were not well explained by macromolecule percentages. This could be due to the fact that the cephalothorax width was harder to measure on *N. crucifera* than *R. punctulata* or because the residuals correlate with carbohydrates, which were not measured in this study.

Body condition residuals in *R. punctualata* were correlated with higher lipid percentages. This means that individuals with better body condtion had a higher lipid percentage. Meaning that body condition residuals are a good measure of fitness for *R. punctulata.*

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